RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

VOLUME LXIII.

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**CALCUTTA: GOVERNMENT OF INDIA
CENTRAL PUBLICATION BRANCH
1930**

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RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 1.] 1930. [May.

GENERAL REPORT FOR 1929. BY SIR EDWIN PASCOE, M.A., Sc.D. (CANTAB.), D.Sc. (LOND.), F.G.S., F.A.S.B., *Director, Geological Survey of India.*

DISPOSITION LIST

DURING the period under report the officers of the Department were employed as follows :—

Superintendents.

DR. L. L. FERMOR . .	Granted combined leave for eight months and twelve days with effect from the 1st March, 1929. Permitted to attend the XVth International Geological Congress held in Pretoria during July and August, 1929. Returned from leave and resumed duty on the 4th November, 1929. Remained at headquarters.
DR. G. E. PILGRIM . .	Returned from leave and resumed duty on the 30th October, 1929. Remained at headquarters as Palæontologist from the 30th October, 1929.

MR. G. H. TIPPER . . Retired from service with effect from the 6th September, 1929.

DR. G. DE P. COTTER. . Returned from the field on the 27th June, 1929. Acted as Palæontologist from the 28th June to the 18th October, 1929. Granted combined leave for fourteen months with effect from the 19th October, 1929, with permission to prefix the Puja holidays.

DR. J. COGGIN BROWN . Granted combined leave for seven months with effect from the 22nd March, 1929. Returned from leave on the 20th October, 1929; placed in charge of the Burma party.

MR. H. C. JONES . . Acted as Palæontologist till the 27th June, 1929. Granted combined leave for fifteen months with effect from the 6th September, 1929.

DR. A. M. HERON . . Appointed Superintendent, Geological Survey of India with effect from the 6th September, 1929. Placed in charge of the Rajputana party; left for the field on the 25th October, 1929.

Assistant Superintendents.

DR. A. M. HERON . . Returned from the field on the 17th May, 1929. Confirmed in the grade of Superintendent with effect from the 6th September, 1929.

DR. C. S. FOX . . . Remained at headquarters to complete the memoirs on the coalfields of India.

MR. H. CROOKSHANK .	Returned from the field on the 19th April, 1929. Placed in charge of the Central Provinces party. Left for the field on the 1st November, 1929.
MR. G. V. HOBSON . .	Returned to headquarters from field work in the Northern Shan States, Burma, on the 16th June, 1929. Placed in charge of the Bihar and Orissa party; left for the field on the 26th October, 1929.
MR. E. L. G. CLEGG . .	Remained at headquarters in charge of office.
RAO BAHADUR S. SETHU RAMA RAU.	Returned from the field on the 17th March, 1929. Died on the 27th March, 1929.
RAO BAHADUR M. VINAYAK RAO.	Returned from field work in the Madras Presidency on the 2nd May, 1929. Granted leave on average pay for two months and twenty-six days with effect from the 10th July, 1929 with permission to affix the Puja holidays. Returned from leave and resumed duty on the 8th October, 1929. Detailed for the continuance of the survey of the North Arcot, Chittoor and Salem districts.
MR. E. J. BRADSHAW .	Continued to act as Resident Government Geologist, Yenangyaung, till the 17th March, 1929. Placed temporarily in charge of the Burma party during the absence on leave of Dr. J. Coggin Brown. Granted combined leave for two years and four months with effect from the 26th October, 1929.

MR. A. L. COULSON . . Continued to act as Curator of the Geological Museum and Laboratory till the 17th May, 1929. Granted combined leave for fifteen months with effect from the 21st May, 1929.

MR. D. N. WADIA . . Returned from the field on the 12th July, 1929. Acted as Palæontologist from the 19th to the 29th October, 1929. Remained at head-quarters.

DR. J. A. DUNN . . Returned from the field on the 21st April, 1929. Acted as Curator of the Geological Museum and Laboratory from the 18th May, 1929.

MR. C. T. BARBER . . Returned from leave on the 10th March, 1929. Resumed charge of his duties as Resident Geologist at Yenan-gyaung and Official Member of the Advisory Boards of the Yenan-gyaung and Singu Oil Fields, Burma, from the 18th March, 1929.

MR. E. R. GEE . . Returned from the field on the 5th July, 1929. Detailed for the resumption of his survey of the Salt Range in the Punjab. Left for the field on the 21st October, 1929.

MR. W. D. WEST . . Returned from leave and resumed duty on the 23rd September, 1929. Attached to the Central Provinces party to continue his survey of the Chhindwara and Nagpur districts till March, when he will resume the survey of the N.W. Himalaya. Left for the field on the 15th November, 1929.

MR. A. K. BANERJI .	. On leave.
DR. M. S. KRISHNAN	. Returned from the field on the 16th April, 1929. Services placed at the disposal of the Department of Education, Health and Lands for a period of three months with effect from the 1st July, 1929. Detailed for the continuance of the survey of Gangpur State in Bihar and Orissa. Left for the field on the 14th November, 1929.
MR. P. LEICESTER .	. Returned to Rangoon from field work in the Amherst district, Burma, on the 18th April, 1929. Granted leave on average pay for eight months with effect from the 3rd May, 1929.
DR. S. K. CHATTERJEE	. Returned from the field on the 22nd April, 1929. Attached to the Central Provinces party and left for the field on the 3rd November, 1929.
MR. J. B. AUDEN	. Returned from leave and resumed duty on the 9th September, 1929. Attached to the Rajputana party till March when he will resume the survey of the N.W. Himalaya. Left for the field on the 11th October, 1929.
MR. V. P. SONDHI .	. Attached to the Burma party to continue the geological survey of the Shwebo district. Remained in Burma throughout the period under report.

MR. B. B. GUPTA . .	Returned to Rangoon from field work in Burma on the 5th May, 1929, and crossed to Calcutta for recess on the 16th May, 1929. Transferred from the Burma party to headquarters and attached to the Madras party. Left for the field on the 8th November, 1929.
DR. H. L. CHHIBBER .	Returned to Rangoon from field work in the jade mines area in the Myitkyina district, Burma, on the 19th May, 1929. Remained in Burma throughout the period under report.
DR. P. K. GHOSH . .	Appointed Assistant Superintendent, Geological Survey of India; joined the Department on the 4th September, 1929. Attached to the Rajputana party and left for the field on the 24th October, 1929.
DR. M. R. SAHNI . .	Appointed Assistant Superintendent. Geological Survey of India; joined the Department on the 14th October, 1929. Attached to the Burma party and left for Burma on the 4th November, 1929.

Chemist.

DR. W. A. K. CHRISTIE .	Remained at headquarters.

Artist.

MR. K. F. WATKINSON .	Remained at headquarters.

Sub-Assistants.

MR. D. S. BHATTACHARJI .	Returned from field work in the Central Provinces on the 20th April, 1929. Attached to the Central Provinces party and left for the field on the 4th November, 1929.
MR. B. C. GUPTA . .	Returned from field work in Rajputana on the 3rd May, 1929. Attached to the Rajputana party and left for the field on the 6th November, 1929.
MR. H. M. LAHIRI . .	Returned from the field on the 1st January, 1929. Attached to the Punjab and North-West Frontier party and left for the field on the 7th November, 1929.
DR. L. A. NARAYANA IYER	Returned from leave on the 15th August, 1929. Attached to the Burma party and left for the field on the 14th November, 1929.
MR. P. N. MUKERJEE .	Returned from the field on the 20th May, 1929. Granted leave on average pay for four weeks with effect from the 19th October, 1929. Returned from leave and resumed duty on the 16th November, 1929. Remained at headquarters during the rest of the period.
MR. A. K. DEY . .	Returned from the field on the 28th April, 1929. Attached to the Bihar and Orissa party to complete the survey of the Palamau district. Left for the field on the 11th November, 1929.

Assistant Curator.

MR. P. C. ROY . . At headquarters till the 24th October, 1929. Granted leave on average pay for two months with effect from the 25th October, 1929.

Assistant Chemist.

MAHADEO RAM . . Promoted to the newly created post of Assistant Chemist with effect from the 8th May, 1929. Remained at headquarters.

Field Collectors.

N. K. N. AIYENGAR . . Remained at headquarters till the 29th October, 1929. Detailed for the collection of fossils in Rewa State. Left for the field on the 30th October, 1929.

AUSTIN M. N. GHOSH . On leave.

Museum Assistants.

D. GUPTA . . . At headquarters.

A. B. DUTT . . . Appointed on the 18th March, 1929. Remained at headquarters.

K. P. HARAN . . . Appointed temporarily on the 30th August, 1929. Remained at headquarters.

M. S. VENKATRAM . . Appointed temporarily on the 5th September, 1929. Remained at headquarters.

The cadre of the Department continued to be 6 Superintendents, 22 Assistant Superintendents, and one Chemist. There were two vacancies in the grade of Assistant Superintendent and these were filled up during the year under report

ADMINISTRATIVE CHANGES.

Promotion and appointments.

Dr. A. M. Heron continued to officiate as Superintendent up to the 5th September, 1929, *vice* Mr. G. H. Tipper on leave, and was confirmed in the appointment of Superintendent with effect from the 6th September, 1929.

Dr. C. S. Fox officiated as Superintendent up to the 29th October, 1929, *vice* Dr. G. E. Pilgrim on leave, and again from the 30th October, 1929 onwards, *vice* Dr. G. de P. Cotter on leave.

Mr. H. Crookshank officiated as Superintendent from the 6th September, 1929 to the 29th October, 1929, *vice* Mr. H. C. Jones on leave.

Mr. G. V. Hobson officiated as Superintendent from the 6th September, 1929 to the 19th October, 1929, *vice* Dr. J. Coggin Brown on leave, and from the 20th to the 29th October, 1929, *vice* Dr. G. de P. Cotter on leave; and again from the 30th October, 1929 to the 2nd November, 1929, *vice* Mr. H. C. Jones on leave.

Mr. E. L. G. Clegg officiated as Superintendent from the 29th February, 1929 to the 2nd November, 1929, *vice* Dr. L. L. Fermor on leave, and again from the 3rd November, 1929 onwards, *vice* Mr. H. C. Jones on leave.

Mr. A. L. Coulson acted as Curator, Geological Museum and Laboratory, till the 17th May, 1929, when he was relieved by Dr. J. A. Dunn.

Mr. H. C. Jones acted as Palæontologist till the 27th June, 1929, when he was relieved by Dr. G. de P. Cotter. From the 19th to the 29th October, 1929 Mr. D. N. Wadia acted as Palæontologist, and thereafter Dr. G. E. Pilgrim.

Dr. P. K. Ghosh, M.Sc. (Cal.), Ph.D., D.I.C., D.Sc. (London), and Dr. M. R. Sahni, M.A. (Cantab.), Ph.D., D.I.C., D.Sc. (London),

F.G.S., have been appointed Assistant Superintendents with effect from the 4th September, 1929 and the 14th October, 1929, respectively.

Mahadeo Ram was appointed Assistant Chemist with effect from the 8th May, 1929.

A. B. Dutt, M.Sc. (Cal.), was appointed Museum Assistant on the 18th March, 1929. K. P. Haran, B.A. (Madras), and M. S. Venkatram, B.A. (Madras), were appointed temporary Museum Assistants with effect from the 30th August, 1929 and the 5th September, 1929, respectively.

Retirement.

Mr. G. H. Tipper retired from the service with effect from the 6th September, 1929.

Leave.

Dr. L. L. Fermor was granted combined leave out of India for eight months and twelve days with effect from the 1st March, 1929.

Dr. G. de P. Cotter was granted combined leave out of India for fourteen months with effect from the 19th October, 1929.

Mr. H. C. Jones was granted combined leave out of India for fifteen months with effect from the 6th September, 1929.

Rao Bahadur M. Vinayak Rao was granted leave on average pay for two months and twenty-six days with effect from the 10th July, 1929.

Mr. E. J. Bradshaw was granted combined leave out of India for two years and four months with effect from the 26th October, 1929.

Mr. A. L. Coulson was granted combined leave out of India for fifteen months with effect from the 21st May, 1929.

Mr. P. Leicester was granted leave out of India on average pay for eight months with effect from the 3rd May, 1929.

Mr. P. N. Mukerjee was granted leave on average pay for four weeks with effect from the 19th October, 1929.

Mr. P. C. Roy was granted leave on average pay for two months with effect from the 25th October, 1929.

LECTURESHIPS.

Mr. E. L. G. Clegg acted as a part-time Lecturer on Geology at the Bengal Engineering College, Sibpur, from the 22nd May, 1929.

Mr. A. L. Coulson continued as part-time Professor of Geology at the Presidency College, Calcutta, till the 17th May, 1929, and thereafter Dr. J. A. Dunn from the 2nd July, 1929.

Dr. M. S. Krishnan acted as a whole-time Lecturer on Geology at the Forest College, Dehra Dun, for a period of three months from the 1st July, 1929.

LIBRARY.

The additions to the Library amounted to 3,574 volumes, of which 1,205 were acquired by purchase and 2,369 by presentation and exchange.

PUBLICATIONS.

The following publications were issued during the year under report :—

1. Records, Vol. LXI, Part 4.
2. Records, Vol. LXII, Part 1.
3. Records, Vol. LXII, Part 2.
4. Records, Vol. LXII, Part 3.
5. Memoirs, Vol. LII, Part 2.
6. Memoirs, Vol. LIII.
7. Memoirs Vol. LIV.
8. Palæontologia Indica, New Series, Vol. X, Memoir No. 3, fasc. II.

MUSEUM AND LABORATORY.

Staff.

Mr. A. L. Coulson was Curator of the Geological Museum and Laboratory from the commencement of the year until the 20th May, when he proceeded on leave. Dr. J. A. Dunn took over the duties of Curator from the 21st May. Babu Purna Chandra Roy, Assistant Curator, proceeded on leave from the 25th October until the end of the year, during which period Babu Mahadeo Ram officiated as Assistant Curator. Babu Dasrathi Gupta continued as Museum Assistant throughout the year, and on the 18th March, 1929 Babu A. B. Dutt was appointed as an additional Museum Assistant. Babus K. P. Haran and M. S. Venkatram assumed the duties of temporary Museum Assistants on the 30th August, 1929 and 5th September, 1929, respectively.

Babu Mahadeo Ram continued as Laboratory Attendant from the beginning of the year until the 8th May, 1929 when he was appointed to the newly created post of Assistant Chemist. This he continued to fill during the remainder of the year, assuming also the duties of Assistant Curator from the 25th October until the end of the year during the absence on leave of Mr. Purna Chandra Roy.

Chemist.

Dr. W. A. K. Christie continued as Chemist throughout the year.

Determinative work and analyses.

The number of specimens referred to the Curator during the year for examination and report was 761, of which analyses, assays, and other special determinations were made of 102. The corresponding figures for 1928 were 722 and 140, respectively. Chemical work included analyses of coal, lignite, coke, clay, carbonaceous shale, laterite, bauxite, dolerite and peridotite; analyses of manganese, zinc, lead and copper ores; and assays for gold and silver.

Donations to Colleges, etc.

During the year under review collections of Indian minerals and rock specimens were donated to the following institutions :-

1. The Bishop Westcott Boys' School, Namkum, Ranchi.
2. The Calcutta Medical College, Biology Department.
3. The College of Engineering, Guindy, Saidapet, Madras.
4. The Dow Hill Girls' School, Kurseong.
5. The Forest Research Institute, Dehra Dun.
6. The Gujarat College, Ahmedabad.
7. The Patna College.
8. The Punjab Agricultural College, Lyallpur.
9. The Victorian Technical Institute, Amraoti.
10. The Cornell University, New York.
11. The University of Madras.

In addition the following specific presentations were made :—

1. A fragment of the Naoki meteorite to the British Museum (Natural History).
2. A fragment of the Naoki meteorite to the Muséum National d'Histoire Naturelle, Paris.
3. Albite to Dr. E. Spencer, Bird & Co., Calcutta.
4. Laurvikite to Dr E. Spencer, Bird & Co., Calcutta.
5. Vitrain to the Principal, Technological Institute, Cawnpore.
6. Basalts to Professor Lacroix, Muséum National d'Histoire Naturelle, Paris.
7. Corundum-bearing rocks to Professor Lacroix, Muséum National d'Histoire Naturelle, Paris.
8. Elæolite-syenites to Professor Lacroix, Muséum National d'Histoire Naturelle, Paris.

9. Rocks associated with Jadeite to Professor Lacroix, Muséum National d'Histoire Naturelle, Paris.
10. Hollandite to H. Bertram Bateman, Esq., London.
11. Piedmontite to Professor J. Jakob, Zürich.
12. Talc to the Institute of Economic Mineralogy and Metallurgy, Moscow.
13. Molybdenite to Sir C. V. Raman, Calcutta.
14. Sodalite-bearing rocks from Kishengarh to the British Museum (Natural History).
15. Manganese ore to C. Wendler, Geneva.
16. Wolfram to C. Wendler, Geneva.
17. Triplite to C. Wendler, Geneva.
18. Corundum to C. Wendler, Geneva.
19. Garnet to C. Wendler, Geneva.

Additions to collections.

Apart from the large number of specimens collected by members of the Department, the following important Indian specimens were received and included in the Museum collections :—

1. Stone meteorite ; from Naoki, Parbhani district, H. E. H. the Nizam's Dominions—Mr. G. H. H. Mills.
2. Apophyllite with laumontite and calcite ; Ooregum Mine, Mysore, South India—Mr. H. M. A. Cooke.
3. Atacamite ; Palamau district, Bihar—Mr. A. E. Newell.
4. Bababudanite in magnetite-quartzite ; Kadur district, Mysore—Director, Mysore Geological Department.
5. Laumontite with apophyllite and calcite ; Ooregum Mine, Mysore, South India—Mr. H. M. A. Cooke.
6. Pyromorphite ; Chandan, Bhagalpur district, Bengal—Mr. T. Chowdry.
7. Samarskite ; Jogipalli, Shrotriem, Nellore, Madras—Mr. R. K. Srinivasan.
8. Sulphur ; Kohat, N. W. Frontier Province—Commissioner of Peshawar.
9. Wad ; Pani Mine, Udaipur, Rajputana—Manager, Pani Mine.
10. Wolfram ; Pagaye Mine, Tavoy, Burma—The Bombay Burma Trading Co., Ltd.
11. Anthracite ; Kalakot, Jammu, Kashmir—Mr. C. S. Middlemiss, C.I.E.

12. Specimens of coal; Burkar, Sohagpur, South Rewa, Central India—Mr. J. Thomas.
13. Striated and facetted pebbles; Kashmir—Mr. R. D. Thompson.
14. Panjal Traps; Bren Spur, Srinagar, Kashmir—Mr. C. S. Middlemiss, C.I.E.
15. Specimens of raw materials used in iron and steel manufacture—Bengal Iron Co.
16. Jet (vitrain); Budhan, Jammu, Kashmir—Mr. C. S. Middlemiss.

The following foreign specimens were added to the collections of the Department :—

1. Collection of Nickel, cobalt, copper, lead, silver, iron ores, and asbestos; from Canada—Mr. H. C. Jones.
2. Eucolite in nepheline syenite; Los Islands, W. Africa—Professor Lacroix, (by exchange).
3. Schillerised felspars; United States—Dr. E. Spencer.
4. Villiaumite and eucolite in nepheline syenite; Los Islands, W. Africa—Professor Lacroix, (by exchange).
5. Coal, Disko Island, off the W. coast of Greenland—Mr. C. A. John Hendry.
6. Alkaline syenites; Xa-Thi, Indo-China—Professor Lacroix, (by exchange).
7. Some basic igneous rocks from Canada—Mr. H. C. Jones
8. Collection of rocks associated with iron ores of the United States—Mr. H. C. Jones.
9. Collection of metamorphic rocks from the S. W. Highlands, Scotland—Mr. W. D. West.
10. Facetted and striated pebbles; Upernivik, Greenland—Mr. C. A. John Hendry.
11. Oil shales; Green River, Colorado—Mr. C. T. Barber.
12. Manganese minerals, rhodonite, friedelite, tephroite and rhodocroisite—Professor Lacroix.
13. Queluzite (spessartite-quartz-rock); Queluz Mines, Brazil—Professor Lacroix.
14. Moonstones; Ambalangoda, Ceylon—Dr. E. Spencer.
15. Opalised shell ('Venus'); Stuart Range, South Australia—by purchase.
16. Specimens of typical salt imported into India—Dr. W. A. K. Christie.

Meteorites.

No falls of meteorites were recorded during the year under review. The meteoric shower of the 29th September, 1928 at Naoki, Hyderabad (Deccan), was recorded in the report for 1928. Another stone which fell near Naoki on the same date was procured from an Arab named Abdulla of Nander by Mr. Mills, of the Criminal Investigation Department, and presented to this Department on the 23rd January, 1929. When received it weighed 1,762·55 grammes. It was broken into fragments, of which one was presented to the British Museum and another to the Muséum National d'Histoire Naturelle, Paris; the remainder was registered as No. 294.

The 'Statesman' of the 31st May, 1929, recorded the fall of a 'meteorite' in Secunderabad which was said to have struck a Miss Lilian Greig. A fragment of the material sent to this Department, however, was identified as coal shale.

Burma Laboratory.

After his return from deputation to Calcutta for training, Mr. L. R. Sharma continued his duties as Chemical Assistant to the Burma party. Up to the end of October, 1929, 75 specimens were received and reported upon in the laboratory of the Burma party of which 18 were quantitatively examined. Specimens examined during the year included rocks from the districts of Insein, Toungoo, Mergui, Kyaukse, Sagaing, Mandalay, Myitkyina and the Shan States. Complete chemical analyses were made of mica from Mergui, felspar from the Ruby Mines district, limestones from the Shan States, jadeite and brines from Myitkyina, and of coal and carbonaceous shales from the Southern Shan States. Various ores of lead and silver, antimony, tin, and zinc were assayed and their metallic contents determined.

To the Museum attached to the office upwards of 460 specimens of rocks, minerals, and fossils were added during the year; of especial interest amongst these was a large collection of rocks associated with the jadeite occurrences of the Myitkyina district collected by Dr. H. L. Chhibber, and specimens of oil shale and the oil distilled therefrom which were brought by Mr. C. T. Barber from the United States of America.

A collection of 20 trimmed rock specimens to illustrate questions of underground water supply, was presented to the Harcourt Butler Institute of Public Health, Rangoon.

DRAWING OFFICE.

The Artist Mr. K. F. Watkinson remained in charge throughout the year. The Head Litho-Draftsman, Rai Sahib Kali Dhan Chandra, retired on superannuation after 35 years' service in the Drawing Office. He joined the department from the Government School of Art at a time when the whole of the maps and illustrations for publication were drawn by hand and printed from wood blocks or by lithography. He showed considerable skill in drawing fossils and in reproducing officers' field sketches on stone. During later years the hand work having been largely superseded by photography, 'Kali Babu'—as he was familiarly known—was put in charge of geological maps, and on many occasions acted for the Artist as head of the Drawing Office. For his long and faithful service he was awarded the title of Rai Sahib in 1928.

Publications.

The preparation of maps for forthcoming Memoirs has occupied the draftsmen for the greater part of the year. The Drawing Office prepared 82 plates and printed 61,560 impressions for publication. In addition 48 drawings were prepared and blocks made for text figures. The Survey of India printed 7 plates numbering 5,800 impressions. Plates specially printed in England for the Palæontologia Indica numbered 18,450 impressions from 41 plates.

Geological maps.

The drawing work of the 32-mile geological map of India having been completed at the end of 1928, the Survey of India Photo and Litho Office have prepared the necessary colour plates. An experimental sheet (No. 2, Punjab) was prepared and proved satisfactory, and it is hoped that the maps will be printed off during 1930. Topographical maps received into stock from the Survey of India numbered 2,700. Some 42 geologically coloured maps were submitted for storing. Considerable progress has been made in compiling a catalogue of maps published in the Records and Memoirs.

Photographic Section.

The work of the photographic section continues to increase, and some 1,975 photographic prints were made to illustrate reports and for reproduction. The stock of registered negatives has been increased by 320 and of lantern slides by over 200.

PALÆONTOLOGY.

Mr. H. C. Jones continued to fill the post of Palæontologist up to the 27th June, 1929. Dr. G. de P. Cotter took charge from the 28th

June until the 18th October, Mr. D. N. Wadia from the 19th October till the 29th October and Dr. G. E. Pilgrim from the 30th October till the end of the year. Sub-Assistant H. M. Lahiri assisted the Palæontologist with routine museum work and with the determination of specimens till the first week of November when he left for the field. Sub-Assistant P. N. Mukerjee on his return from leave in the middle of November assisted the Palæontologist with the above duties till the end of the year.

Two new appointments to the post of Museum Assistant were filled by K. P. Haran and M. S. Venkatram in August and September 1929 respectively. The former has resumed the work of cleaning and replacing labels in the large Klipstein Collection stored in the Invertebrate fossil gallery. The latter is engaged in routine work connected with palæontology.

Mr. F. E. Eames, Palæontologist to the Burmah Oil Company, visited Calcutta towards the end of the year, with the object of utilizing the Survey fossil collections for the determination of material recently collected by the Company's geologists.

Mr. A. T. Hopwood of the Geological Department of the British Museum, whose deputation to India in order to revise the collections of fossil Proboscidea was referred to in the last General Report (*Rec. Geol. Surv Ind.*, LXII, p. 19), left Calcutta on May 9th after just under six months' work. He succeeded in completing his determinations of the Mastodontinae, which embrace nearly all the specimens from the Gaj to the Dhok Pathan horizon inclusive. The Stegodontinae and the Elephantinae have been only casually examined. These, however, are of less importance, as they are for the most part of Upper Siwalik age and the large collections from that horizon in the British Museum will supply almost all the material and information required. Mr. Hopwood is now engaged in writing a memoir on the group for the *Palæontologia Indica.* The drawings required for this have been prepared in Calcutta and will shortly be ready for reproduction.

In order to facilitate Mr. Hopwood's comparison of certain Indian specimens with European types, casts have been made of a number of the specimens to be figured, and these as well as several duplicates have been sent to him at the British Museum. These will not be returned, but will be presented to the British Museum, who propose to present us with a set of casts of British Museum specimens by way of exchange.

C

During 1929 the following memoir has been published in the *Palæontologia Indica* :—

(1) H. Douvillé : 'Les Couches à Cardita Beaumonti dans le Sind.' Fasc. I of Memoir No. 3, Vol. X of the New Series.

The following papers of palæontological interest have appeared in the Records :—

(1) 'New Devonian Fossils from Burma,' by F. R. Cowper Reed. (Vol. LXII, pt. 2).
(2) 'The Permo-Carboniferous Succession in the Warcha Valley, Western Salt Range, Punjab,' by F. R. Cowper Reed, G. de P. Cotter and H. M. Lahiri. (Vol. LXII, pt. 4).
(3) 'Note on the alleged occurrence of fossil eggs at Yenangyaung, Upper Burma,' by C. T. Barber. (Vol. LXII, pt. 4).

The following papers of palæontological interest are in the Press, and are expected to be published in 1930 :—

Palæontologia Indica.

(1) L. F. Spath : 'Revision of the Jurassic Cephalopod Fauna of Kachh.' Part IV of Memoir No. 2, Vol. IX of the New Series.
(2) B. Sahni : 'Revisions of Indian Fossil Plants : Coniferales (b. Petrifactions).' Part II of Vol. XI of the New Series.
(3) Lt.-Col. L. M. Davies, Ethel D. Currie, Helen M. Muir-Wood, L. R. Cox, L. F. Spath and J. W. Gregory : 'The Fossil Fauna of the Samana Range.' Parts I to VIII of Vol. XV of the New Series.
(4) F. R. Cowper Reed : 'Upper Carboniferous Fossils from Tibet.' Vol. XVI of the New Series.
(5) F. R. Cowper Reed : 'New Fossils from the Productus Limestones of the Salt Range, with notes on other Species.' Vol. XVII of the New Series.

Records.

(6) C. S. Fox : 'Note on Cretaceous Cephalopods from Kalaw, Southern Shan States, Burma.'

(7) J. W. Gregory, J. Weir, J. Pia, and F. Trauth: 'Upper Triassic Fossils from the Burmo-Siamese Frontier.'

Amongst the as yet unpublished papers listed above, in No. 1 Dr. L. F. Spath concludes his revision of the Jurassic Cephalopoda of Kachh.

In No. 2 Prof. B. Sahni concludes that portion of his monograph which deals with the fossil conifers of India with a comprehensive description of the known Indian petrifactions, of which the petrified woods are referred to thirteen and the ovuliferous cones to three species, almost all new; there are besides a number of specimens which are too imperfectly preserved for specific determination. The monograph includes the first fossil conifers to be described from Burma and the only petrified cones so far discovered in India. The last few pages of his paper summarize the known facts on the distribution of the group in India, Burma and Ceylon and on their geological history. While its existence in Lower Gondwana times is at any rate doubtful, it flourished during the Upper Gondwana period, apparently reaching its zenith in Jurassic times and declining during the Cretaceous. It is interesting to observe that during this period the occurrence of conifers is practically confined to peninsular India, Burma and Ceylon, and so differs entirely from that which obtains to-day. Professor Sahni is led to conclude from the fact that no record of a gymnosperm exists in the Tertiaries of India, with the sole exception of *Mesembrioxylon schmidianum* from Southern India, that this group became practically extinct in this part of the world, and that the present coniferous flora of the Himalaya is a comparatively recent invasion from without. The important bearing which certain of the palæobotanical results elicited have on the stratigraphy and classification of the Gondwanas has been mentioned in the last General Report (*Rec. Geol. Surv. Ind.*, LXII, p. 28) and need not be repeated.

A summary of the results of the work on the fossil fauna of the Samana Range, which is the subject of No. 3 paper, has already been given in the last General Report (p. 20).

Dr. F. R. Cowper Reed's memoir (No. 4) on the Upper Carboniferous fossils collected by the late Sir Henry Hayden during his last journey (1921) in Tibet, entirely confirms Hayden's correlation of this horizon. No definite Permian element is recognizable from any of the localities, nor do the typical species of the Productus limestone of the Salt Range occur. On the other hand the brachiopoda are

almost without exception known from the Upper Carboniferous of the Urals or parts of Asia and the prevalence of *Schwagerina princeps* is strongly suggestive of the Uralian.

A paper published in part 4 of the *Records* (Vol. LXII, p. 412 *et seq*) by Dr. F. R. Cowper Reed, Dr. G. de P. Cotter and Mr. H. M. Lahiri gave the stratigraphical results of their expedition to the Salt Range early in 1928. No. 5 in the list deals with the palæontology. Complete lists of the fossil species now described have already appeared in the paper referred to.

Dr. C. S. Fox' discovery in the sandstones of Kalaw (20° 38′ 15″; 96° 37′), in the Southern Shan States of Burma, of fossils which turn out to be of Cretaceous age, possesses considerable interest not only in itself but also because it produces a possible link between the Mesozoic formations of the Northern and the Southern Shan States; this is welcome evidence, since the field work as yet done is insufficient for definite correlation. Dr. Fox deals with his discovery and the indications which it affords in a note published in the present part (p. 182 *et seq*), being No. 6 of the prospective papers quoted above.

No. 7 contains the description of an interesting but small and badly preserved fauna, which Dr. G. de P. Cotter collected in 1921 from the Kamawkala limestone in or near the Kamawkala gorge (17° 4′; 98° 25′) of the Thaunggyin river on the Burmo Siamese frontier (*Rec. Geol. Surv. Ind.* LV, p 281). These specimens were examined by Mr. G. H. Tipper, who expressed the opinion that they were of Triassic age. The collection was recently sent to Professor J. W. Gregory who, with the partial collaboration of Dr. J. Weir, Dr. F. Trauth, Dr. J. Pia, Dr. Gyon Arthaber, Dr. L. F. Spath, and Dr. Ethel Currie, has now finished the determination; the results appear in this part of the *Records* (pp. 155-181) under the names of the first four contributors mentioned.

The corals include species of *Stylina Stylophyllopsis Centrastræa* and *Mœandraræa.* The brachiopoda are all Rhynchonellidae referred by Dr. Weir to *R. bambanagensis* Bittner, *R.* aff. *concordiae* Bittner, and *R.* cf. *fissicostata* Suess. A lamellibranch is only identifiable as *Chlamys* sp. Finally a calcareous alga belonging to the family Dasycladacea and allied to *Aciculella* is made by Dr. Pia the type of a new genus and species, *Holosporella siamensis.* In addition the genera *Diplopora*, *Lovencipora*, and *Sphærocodium* have been recognized. There is a unanimity of opinion among the specialists who

have examined the fauna that it is undoubtedly Trias and probably Norian in age.

In the last General Report it was mentioned that the collections made in recent years from the older rocks of the Kala Chitta range in the Attock district had been sent to England for description. From a preliminary examination of the ammonites Dr. Spath has stated that the basal Giumal sandstone includes beds from the top of the Argovian and the Lower Kimmeridgian up to the base of the Cretaceous, while the Upper Giumal ammonites are Albian (Gault) like the Samana and Hazara forms. The fauna from the underlying Trias consists of brachiopods and lamellibranchs. The fossils belonging to these groups, which also form a constituent of the fauna of the Giumals, have not yet been examined by Miss Muir Wood and Mr. L. R. Cox.

During his visit to Afghanistan in 1908 the late Sir Henry Hayden made collections from the Fusulina limestone in the Bamian valley. These were referred to in Volume XXXVIII of the *Records*, p. 252 and in Memoir, XXXIX, pt. 1, pp. 52-54. None of this fauna except the Fusulinidae has been worked out in detail. The remainder, consisting almost entirely of brachiopoda, has now been sent to Dr. F. R. Cowper Reed for description.

A reference was made in the General Report for 1927 to a collection of fossils made by Mr. R. D. Thompson from the Agglomeratic Slate series of the Bren spur near Srinagar, Kashmir. The exceptional interest of this fauna, differing as it does from the fauna from other localities in the same series described by the late Mr. H. S. Bion (*Pal. Ind.* New Ser. XII) induced me to ask Mr. C. S. Middlemiss if further collections could be made from the same place. This he has very kindly done, and the entire collection from the Bren spur including both Mr. Thompson's and Mr. Middlemiss' specimens, is now being described by Dr. F. R. C. Reed. His preliminary examination of it has disclosed the presence of *Eurydesma cordatum* and *Martiniopsis darwini*. The fauna thus corresponds to that of the Lower Speckled Sandstone horizon of the Salt Range but contains a more varied assemblage of forms than those described by Wagan.

During the past field season Mr. E. R. Gee made a small collection of fish scales from the Lower Panchet beds of Kukhrakuri village (86° 58′ 40″; 23° 36′ 55″) south of the Damodar river in the Raniganj coal field. Dr. E. I. White of the Geological Department of the British Museum (Natural History) has been kind enough to examine

these, but unfortunately reports that they are indeterminable with the exception of *Amblypterus*, a genus which ranges from Carboniferous to Permian.

Several small collections of Jurassic plants, many of which have been in the possession of the Department for a considerable time, have recently been sent to Cambridge, where Prof. A. C. Seward and Prof. B. Sahni propose to study them in detail. These are the following :—

Plant remains collected by the late Mr. W. T. Blanford in Persia. They are possibly the ones from the north of Persia referred to in 'Zoology and Geology of Eastern Persia', (1876), p. 506.

A collection made near Kirman by Mr. G. H. Tipper and mentioned by him in Records, Volume LIII, p. 59.

Collections made by Dr. J. Coggin Brown from the Rhætic of Yunnan and Sse-chu-an in China.

Plants collected in 1921 by the late Captain Walker and Dr. G. de P. Cotter, either separately or jointly, from the Loi-an coal measures near Kalaw (20° 38′ 15″; 96° 37′) in the Southern Shan States of Burma. The examination of these plants by Dr. Cotter clearly proved the Jurassic age of the coal, originally thought to be Tertiary, but later suspected by Mr. Middlemiss to be much earlier from their similarity to beds in the Northern Shan States. These plants were determined by Dr. Cotter as the following :—

Cladophlebis denticulata (Brong.),
Gingkoites digitata (Brong.),
Pagiophyllum divaricatum (Bunb.),
Brachyphyllum expansum (Sternb.),
Ptilophyllum sp. cf. *P.* (*non Otozamites*) *hislopi* (Oldh.),
Podozamites distans (Morris.),

During the past year very few fossil specimens have been sent in from the field for determination and these call for no more than brief mention.

Dr. C. S. Fox has just handed in for registration a number of fragments of a siliceous limestone which he collected in 1925 from loose boulders near Jamrud between Peshawar and the Khyber Pass. These are full of badly preserved brachiopoda which Mr. G. H. Tipper thought afforded some indication of a Devonian age.

A few proboscidean teeth were collected by Mr. B. B. Gupta from the lowest beds of the Irrawadian series at two localities in the Shwebo district of Burma. The first is one mile W.S.W. of Aukyedwin (22° 52′ 30″; 94° 50′) and the second one mile and three furlongs N.N.W. of Taungbyinnge (22° 50′ 30″; 94° 49′ 20″). Two of the specimens from the first locality have been referred by Mr. Hopwood of the British Museum to the genera, *Mastodon* (*Tetralophodon*) and *Stegolophodon*, respectively.

A few poorly preserved fossils of Pegu age were collected by Mr. Sondhi at two localities in the Shwebo district. They consist of casts of gastropods and of *Batissa* sp. cf. *kodaungensis* in one case and of *Balanus* sp. with *Turritella* sp. and *Batissa* sp. in the other. The second locality is ¾ mile south-west of Male (23° 1′ 15″; 95° 58′ 15″) while the first is in Latitude 23° 58′, Longitude 95° 58′ 30″.

Mr. C. T. Barber discovered a fossil leaf bed in the Irrawadian approximately 100 feet above the Red Bed in Outer Beme, and a rhinocerotid tooth, said to come from the Pegu rocks of eastern Khodaung, both in the Yenangyaung oilfield of Burma.

In the Southern Shan States Dr. J. Coggin Brown, reports the occurrence of fossiliferous rocks of Naungkangyi (Ordovician) age, containing brachiopods and fragments of trilobites near Sale (20° 48′; 97° 1′) and Ye-o-sin (20° 53′ 39″; 96° 42′ 15″), of Permo-Carboniferous limestones with *Lyttonia*[1] sp. and clisiophyllid corals near Nyaungkaya (20° 54′; 96° 46′ 30″) and of Fusulina limestones near Pindaya (20° 56′ 45″; 96° 42′ 15″).

On the eastern flanks of the Mawson dome, Southern Shan States, phacoidal, argillaceous limestones, containing abundant specimens of *Orthoceras* sp. and probably of Ordovician age, are common.

Still fewer in number and of less importance are the donations to the Department, with one exception, which indeed may be said to represent one of the most valuable accessions to our palæontological collections from an outside source for many years. This consists of the major part of a very large collection of Cephalopoda made from the Cretaceous beds of Southern India by the late Dr. H. Warth and handed over to the museum in Madras about 40 years ago; it comprises over 200 specimens. Of these 103 were figured or described by Dr. F. Kossmat in his monograph, entitled 'Untersuchungen über die Südindische Kreideformation' [*Beitr. Pal. u. Geol.*

[1] Kindly determined by Dr. Stanley Smith of Bristol University.

Ost.-Ung., Vol. IX, (1895), pp. 97-203 and Vol. XI, (1898), pp. 1-152]. These have been exhibited in the Madras Museum for many years. Of the remainder 15 were figured or described by Dr. E. Spengler in his paper 'Die Nautiliden und Belemniten des Trichinopolidistriktes' [*Beitr. Pal. u. Geol. Ost.-Ung.*, Vol. XXIII, (1910)] and 32 by the same author in his 'Nachtrage zur Ober kreidefauna des Trichinopolidistriktes in Südindien" [*Beitr. Pal. u. Geol. Ost.-Ung.*, Vol. XXVI, (1913)] and have been in Vienna until recently.

The question of the transfer of these to the Geological Survey of India arose out of the recent return to Calcutta of the collections from the Cretaceous of Assam described by Dr. E. Spengler in 'Contributions to the Palæontology of Assam' [*Pal. Ind.*, New Ser., Vol. VIII, Mem. 1, (1923)] together with a few of Stoliczka's figured specimens 'Cretaceous Fauna of Southern India,' [*Pal. Ind.*, Vol. II, (1867-68)] and others which he did not figure. These have been in Vienna for some time.

The transfer of the fossils from the Madras to the Indian Museum was effected in accordance with a resolution adopted by the Indian Museums Conference in 1907 that types belonging to Provincial museums should be placed in the Indian Museum, Calcutta. The Geological Survey have presented the Madras Museum with about 160 duplicates from the Cretaceous of Southern India representative of the fauna, to replace the types and figured specimens in the museum galleries.

The Director of the Burma Forest School, Pyinmana, sent some fossils collected in the Myinbin Reserve, from a locality lying in the area mapped as Pegus by the late Captain F. W. Walker. These were identified by Mr. H. M. Lahiri as *Cyrena* (*Batissa*) cf. *kodaungensis* Noetl., *Cyrena* (*Batissa*) sp., and some fossil wood.

Two badly preserved specimens sent for identification by the Honorary Secretary of the McMahon Museum, Quetta, were provisionally referred by Mr. Wadia to *Natica* and *Plicatula*.

During the year presentations of fossils were made to the following institutions :—

The Intermediate College, Mysore.—A collection of 30 fossils from various geological horizons.

The Dow Hill Girls' School, Kurseong.—A small elementary collection of fossils illustrating the various groups in the animal kingdom.

The Hindu University, Benares.—A large collection of fossils representative of the following faunæ: (1) the Tertiaries of Burma; (2) the Tertiaries of Sind; (3) the Cretaceous of Southern India; (4) the Trias of the Himalaya; (5) the Palæozoics of the Shan States, Burma.

The British Museum (Natural History), Geological Department.—About 100 specimens of fossil Proboscidean teeth from various horizons and 44 plaster casts of fossil Proboscidean teeth, most of which have been already figured or will be figured in Mr. Hopwood's memoir.

The Central Museum, Madras.—A collection of 160 specimens representative of the fauna of the Cretaceous of Southern India.

In response to requests for a cast of the holotype skull of *Hydaspitherium megacephalum* Lydekker, from Professor W. D. Matthew, of the University of California, Berkeley, and for some figured specimens of *Sivapithecus* from Professor J. W. Gregory of the University of Glasgow, and from Dr. W. K. Gregory of the American Museum of Natural History, New York, these were executed and despatched to their respective addresses.

Mention was made in the last General Report (p. 158) of the reported discovery by Dr. R. Van V. Anderson, Menlo Park, California, of dicotyledonous leaves in shale belonging to the upper part of the Saline series in the Khewra gorge of the Salt Range, Punjab. In view of the importance of such a discovery, which, it was claimed, placed the age of the deposits as not older than Lower Cretaceous, Dr. Anderson was asked to allow us to see his specimens. He was kind enough to send his best specimen, but, perhaps due to friction during transit, the specimen, when it arrived, was not determinable in this Department as of organic origin. It is hoped that photographs may have been taken of the specimen before it was despatched through the post. Mr. Gee collected from the same locality numerous specimens with markings of what may or may not have been vegetable or animal remains, but none of his specimens was determinable. Since then he has discovered nummulites in beds which, there seems good reason to believe, belong to the Saline series. If the indigenity of these beds is confirmed, the long disputed question of the age of the Salt marl will be definitely solved.

MINERALOGY.

In response to a request from Professor J. Jakob of the Mineralogisch-Petrographisches Institut, Zürich, a specimen of piedmontite from Kajlidongri, Jhabua State, Central India, presented some years ago by Mr. H. J. Winch, was supplied for analytical investigation. The result is as follows :—

	Per cent.
SiO_2	35·57
TiO_2	0·00
Al_2O_3	18·27
Fe_2O_3	7·06
FeO	0·00
Mn_2O_3	12·43
MnO	2·94
MgO	0·96
CaO	19·53
Na_2O	1·14
K_2O	0·87
H_2O (+110°)	0·85
H_2O (−110°)	0·38
	100·00

Dr. Fermor has described under piedmontite[1] several Indian occurrences, without distinguishing between piedmontite (+ve) and mangan-epidote (− ve). Judging from the proportions of iron and manganese oxides the specimen analysed was a true piedmontite.

Mention was made in the previous Annual Report (p. 134) of the discovery of dumortierite at Mogra and Girola on the southern edge of the Sakoli sheet. Dr. S. K. Chatterjee has since separated and submitted to analysis the dumortierite with the following result :—

	Per cent.
SiO_2	29·78
Al_2O_3	63·39
Ti_2O_3	0·18
B_2O_3	5·49
Fe_2O_3	0·26
FeO	trace
MnO	,,
CaO	absent
MgO	,,
H_2O (+110°)	0·96
H_2O (−110°)	0·04
	100·10

[1] *Mem. Geol. Surv. Ind.*, XXXVII, p. 186.

The specific gravity is 3·27 and the hardness 7; the refractive indices are :—

$$x=1{\cdot}678 \text{ (deep lilac)}$$
$$y=1{\cdot}685 \text{ (colourless)}$$
$$z=1{\cdot}685+0{\cdot}002 \text{ (colourless).}$$

Dr. Chatterjee also records the discovery of roscoelite or vanadium mica. This occurs as olive-green flakes in pegmatite and related quartz veins, and also in association with the adjoining kyanite-bearing rocks of the Sakoli *tahsil.*

International Geological Congress.

The 15th International Geological Congress was held at Pretoria in South Africa in August 1929. Dr. Fermor, who, whilst on leave in England, was deputed to attend this Congress as the representative of the Government of India, arrived in Cape Town on the 15th July and sailed again on the 6th September. During his stay in South Africa, he was able, in addition to attending the meetings at Pretoria, to take part in excursions held before and after the Congress for the purpose of studying the chief geological features and mineral deposits of the country. Before the Congress, he took part in excursions to the Kimberley diamond mines and the Witwatersrand gold mines, as well as studying typical exposures of the Dwyka conglomerate and glaciated pavements in the neighbourhood of Nooitgedacht, near Kimberley. During the session at Pretoria excursions were made to the Rustenburg platinum mines, the alkali syenites of Pilansberg and Franspoort, and the Premier diamond mine, as well as in the neighbourhood of Pretoria. After the Congress, Dr. Fermor joined the excursion to Southern Rhodesia, visiting a selection of the mines of chromite, asbestos, gold and coal of that country, and also some of the occurrences of Archæan schists. Leaving this excursion at the Victoria Falls, he then joined an excursion to Northern Rhodesia. A visit was paid to the Rhodesian Broken Hill lead-zinc mine and to the copper mines and deposits of Bwana-Mkubwa, Nkana, Roan Antelope, and Mufalira. This excursion went as far as Elizabethville in the Belgian Congo, where a brief visit was paid to the Star of the Congo and Ruashi copper mines. On the return journey to Cape Town, Kimberley was revisited and thence a visit was made to the recently discovered manganese ore-deposits of Postmasburg. Dr. Fermor has returned from South Africa impressed with the magnitude

of her resources in diamonds, gold, platinum, copper, manganese, chromite, asbestos and coal. The reserves of copper-ore already proved in Northern Rhodesia are particularly striking. Some 39 different countries were represented in the Congress, and the geologists from abroad were grateful for the excellent arrangements for their visit made by their South African confrères, and for the hospitality generously extended to them by numerous mining companies. Dr. Fermor has brought back a large collection of specimens illustrating the mineral deposits and geological features of the places visited; amongst these mention may be made of rare zinc minerals from Broken Hill, eclogites from the Kimberley region, and specimens illustrating the geology of the copper deposits of Northern Rhodesia.

ECONOMIC ENQUIRIES.

Apatite.

Dhalbhum, Bihar and Orissa.

In Dhalbhum, on either side of the copper belt, there are innumerable veins of chlorite-apatite-magnetite-rock [see also *Rec. Geol. Surv. Ind.*, L, p. 14, (1919)]. Where magnetite is absent and almost pure apatite present the veins have been mined. Several such large veins have been worked in recent years south of Jamshedpur. Dr. Dunn found them all associated with chloriteschist in close proximity to a tongue of granite-schist. He has assumed that the phosphates are genetically related to the original granite. Some such veins are also associated with inclusions of chlorite-schist in the granite-schist. These 'inclusions' evidently have a complex history and may represent completely mylonised and chloritised zones of granite. The apatite veins are in a sense true segregations; there are all gradations from chlorite-magnetite-schist through chlorite-magnetite-apatite-rock and chlorite-apatite-rock to apatite-rock. In Dr. Dunn's opinion the phosphate and fluoride solutions, products of the granite intrusions, reacted on the chlorite-schists. He believes the lime of the epidote gave rise to the apatite, and that this mineral, with the chlorite and magnetite, was subsequently segregated into lens-shaped veins. Later shearing and thrust movements have sheared, disjointed, and contorted these veins. The largest vein, that of Kudada (22°42′; 86°13′), is 300 yards long and 10 feet wide.

Asbestos.

Dr. Dunn records small deposits of tremolitic asbestos, in an altered basic igneous rock, at Manpur (22° 36'; 86° 16') and Digarsai (22° 35'; 86° 14') in Dhalbhum. The asbestos is a short-fibred rather brittle material. None of the occurrences is of economic importance.

Dhalbhum, Bihar and Orissa.

Asbestos of the slip-fibre type was found by Mr. M. Vinayak Rao at the southern extremity of the magnesite deposit in the Chettichavadi *jaghir*, Salem district, Madras (*q.v.*).

Salem District, Madras.

Bauxite.

On the top of the Jogi Tilla escarpment of the eastern Salt Range, Punjab, a bed of pisolitic bauxite in association with the basal laterite of the Nummulitic series is reported by Mr. Wadia. The mineral occurs as a clean, brown or buff cap, passing gradually into pisolitic laterite. The percentage of Al_2O_3 is 53·1.

Jhelum District, Punjab.

Building Materials.

The abutments of the bridges of the Mogaung-Kamaing road in the Myitkyina district of Burma are built either of limestone or of serpentine. Quarries for both these materials have been opened up in the Hkakon Hka (Sheet 92 C/11) about ¾ mile west of the first bridge in the 22nd mile of the road. Dr. Chhibber, at the request of the local officials, examined a number of rocks which it is proposed to use for road metal in the Mogaung subdivision. In his opinion the crystalline schists of the Sawngching Hka (25° 19' 23"; 96° 44' 23"), of Namti (25° 21' 50"; 97° 15' 23") and of the Wolai Hka (25° 8' 36"; 96° 40' 18".) are the most suitable; after these come the serpentines of Pidaung (25° 25' 25"; 97° 15' 2"), at the 16th mile on the Hopin-Nampadaung road and the 22nd mile on the same road. The softer Tertiary sandstones should only be employed when the harder rocks are not available.

Myitkyina District, Burma.

In the neighbourhood of Kyauksegan (22° 57'; 95° 39' 30"), Shwebo district, Burma, Mr. Sondhi reports that laterite is found in the Irrawadian sands, near their junction with the alluvium. The sand is rich in small ferruginous concretions, and the laterite appears

Shwebo District, Burma.

to have originated by cementation of the residual accumulations of these concretions. The rock does not form a continuous bed of regular thickness but occurs in a haphazard manner, having any thickness up to twelve feet. It is extensively quarried north of the above named village on behalf of the Public Works Department, and is used for facing canal embankments and in bridge construction.

Basalt is quarried for use as road metal at Wetpyu Taung (22° 49′ ; 95° 11′). The rock cuts through the Irrawadian sand and stands in a dome-shaped hill half-a-mile in diameter with a height of over one hundred feet. It is one of the best road metals of the district but has the disadvantage of having to be transported by bullock carts for about 20 miles before it can be put to any use.

Marble: Hazara District, Punjab.

Large lenticular masses, of some hundred yards linear extent, of pure white coarsely crystalline marble are frequent constituents of the Salkhala series of Kaghan in the Hazara district of the Punjab and of its southern continuation into the Balgran area of the Muzaffarabad district, Kashmir. Mr. Wadia remarks that this marble would be a much-valued ornamental stone but for its remoteness from any considerable centres of population.

Chromite.

Myitkyina District, Burma.

In addition to the occurrences of chromite found in association with the peridotites and serpentines of the Jade mines region of Upper Burma and mentioned in the General Report for 1928, Dr. Chhibber has found blocks and boulders of chromite during the present season at the following additional localities :—

(1) In a tributary of the Pang Hka, nearly one mile W. N. W. of Mahok (25° 44′ 8″ ; 96° 22′ 53″).

(2) Near the old jadeite working of Pangmaw (25° 44′ 53″ ; 96° 20′ 54″).

(3) On the track from Namshamaw (25° 45′ 31″ ; 96° 22′ 28″) to Mawsitsit and also in the neighbourhood of Wayutmaw (25° 45′ 42″ ; 96° 21′ 38″).

(4) In the Nanjo Hka, about 6½ furlongs north of Sanhka (25° 41′ 8″; 96° 20′ 57″) where chromite boulders are associated with a volcanic breccia.

(5) In the Tertiary conglomerates of Pangmamaw, east of Kansi (25° 47′ 1″ ; 96° 22′ 48″).

In no case was the mineral abundant enough to be worth exploitation.

Salem District, Madras.

Chromite was observed by Mr. M. Vinayak Rao occurring at the northern extremity of the magnesite deposit of the Chettichavadi *jaghir*, Salem district, Madras.

Hazara District, Punjab.

Small segregated pieces of chromite were found by Mr. Wadia to occur near Bhunju village, Kaghan valley, Hazara district, Punjab, in a dense black hyperite, formed probably during local differentiation of the dolerite dykes which are of common occurrence in this locality.

Coal.

Upper Chindwin District, Burma.

Two thin seams of shaly coal were found by Mr. B. B. Gupta in beds belonging to the Yaw stage in the Do Chaung, about three miles west of Anauktaw (22° 50′ ; 94° 42′ 30″) in the Upper Chindwin district of Burma. The total thickness is only about 1½ feet and the material is of no economic importance.

Myitkyina District, Burma.

According to Dr. Chhibber coal occurs in the Namjan Hka, a little west of its confluence with the Hlainnawng Hka or about $2\frac{1}{5}$th miles N. N. W. of Namyong (25° 40′ 31″; 96° 26′ 17″) in the Myitkyina district of Burma. There are five seams in all, but only one, the westernmost, is of good bituminous quality ; it is about a foot thick. The others are impure and merge sometimes into black carbonaceous shales. The coal is intercalated in very finely bedded, rather laminated, black carbonaceous shales and sandstones which, close to the coal seam, bear unidentifiable plant impressions. The beds dip to the west at about 75°. A sample from the best seam was found to be non-caking and was analysed with the following results :—

	Per cent.
Moisture	7·31
Volatile matter	19·98
Fixed carbon	37·81
Ash	34·90

In the same stream, near its junction with the Hpakan Hka thin seams and small pockets of bright coal are interbedded with finely bedded sandstones and black carbonaceous shales, dipping at 58° in a direction W.S.W.

About two-and-a-half miles W.N.W. of the village of Thinbaungga (22° 52′ 30″; 95° 59′) in the Shwebo district of Burma, a seam of coal occurs in a soft sandstone of the Irrawadian series, at the crest of an anticline, and dips E.N.E. at 18°, according to Mr. Sondhi. The coal bed is about two feet thick, but the greater part consists of a highly carbonaceous shale with streaks of coal and specks of dark brown resin. The bed is broken by small dip faults with short down-throws to the south. It was worked in a small way a few years ago, but its quality and the quantity proved underground did not justify the continuation of the operations. A few entrances to the deserted shafts are still visible. A mile-and-a-half to the north, pockets of coal are exposed in the sandstone of the Kodaung Chaung and are freely mixed with pyrites.

Shwebo District, Burma.

Copper.

Dr. J. A. Dunn surveyed the eastern section of the Singhbhum copper belt during the field season. His studies lead him to the conclusion that the Archæan fold movements gave rise to a zone of intense shearing in which were formed the copper lodes of Dhalbhum. In the vicinity of the epidiorites, which formed a buttress against these movements, the schists were sheared over a narrow zone and well-defined planes of dislocation formed. Where, however, there was no buttress of epidiorite, the thrust movements were taken up by shearing and contortion and well-defined fissures are more or less absent. Hence, the copper-bearing solutions found the fissures the most favourable channels for ascension and deposition, and thus the most valuable lodes originated. Of the 70 odd miles of the copper belt which have so far been examined by Dr. Dunn only 12 miles seem worthy of attention. He considers that of this 12 miles there are only four places which are likely to have a profitable future. There may of course be small impersistent lodes outside these areas, but they are not likely to be of much consequence.

Singhbhum District, Bihar and Orissa.

The copper lodes occur in different types of country rock. At Nandup they are found in a chloritic schist, at Rakha mines and Chapri in mica-schist, at Kendadih and Surda between mica-schist and quartzite. In the vicinity of the lodes, biotitic and chloritic schists often appear to have been converted to sericite-schists. The

Mushabani lodes occur in sheared zones within granite-schist, whilst the adjacent lodes of Dhobani are apparently within a curious type of biotitic schist. The Dhobani lodes are probably among the largest in the belt.

At Mushabani shear zones in the granite (granitic schist) vary in width from a few inches up to 30 feet. Although these shear zones determine the real width of the lodes, the heavily mineralised part of the lodes are usually much narrower. The workable lodes are characterised by a solid vein of chalcopyrite and pyrrhotite, usually about 9 inches wide but varying up to 2 feet, in partially mineralised country rock. Along this mineralised zone the original granite has been completely altered to a biotite-chlorite-quartz-schist, but there is every gradation between this and unaltered granite; 'horses' of granite are also often met with in the lode. There are at least two large lodes at Mushabani, converging towards the north, and there are also several small lodes to the east and west which may be worth working later. The metallic minerals present are chalcopyrite and pyrrhotite. The presence of the latter necessitates the removal of a rather high nickel content in the subsequent milling and smelting of this mixed ore.

Southern Shan States, Burma.

About half-a-mile E.S.E. of Thegon (20° 42′ 45″ ; 96° 52′ 15″), which is itself one mile south of Heho, a station on the Southern Shan States branch of the Burma Railways and on the lower western slopes of the main Heho range, there is a small patch of ground with no rock *in situ* but which is, according to Dr. Coggin Brown, strewn with small pieces of crumpled and bleached slate and pieces of quartz bearing stains and films of malachite. The rare occurrence of pieces of slag indicates ancient small-scale metallurgical operations in the vicinity.

Engineering and Allied Questions.

Building Sites, Prome Hill, Burma.

When he visited the town of Prome in Burma in connection with the water supply of the civil station, Mr. E. J. Bradshaw was invited to inspect the sites of certain bungalows on Prome hill and to give an opinion on their stability since, owing to the subsidence of the foundations, serious cracks had developed in them. The bungalows are built on steep and narrow spurs composed of alternations of beds

of shale and sandstone with dips of 27° to 30°. Mr. Bradshaw concluded that the trouble is due to surface creep and that the piece-meal descent of the superficial ground is inevitable. Attempts to support the hill-side by small retaining walls or local sheet-piling are doomed to failure and, while it would be possible to reduce the slip by an extensive system of concrete drainage-facing, the cost of adequate measures would probably be several times greater than the cost of the bungalows they were designed to protect.

Quarry Sites, Meiktila District, Burma.

In compliance with a request from the Chief Engineer, Public Works Department, Burma, Mr. V. P. Sondhi was deputed to examine the proposed site of a quarry for road-metal at Shansikangon, about half-a-mile north of the 14-mile-3-furlong post of the Thazi-Taunggyi road. Mr. Sondhi found that the rocks of the site consist of granite-gneiss, biotite-schist, and quartz-porphyry. In his opinion the last named is the best for road metal purposes whilst it and the finer grained granite-gneiss are present in sufficiently large quantities to justify the establishment of a quarry.

Quarry Site, Yamethin District, Burma.

A proposal having been made to establish a large jail-worked quarry near Shwedwin (19° 52′ 48″; 96° 15′), a village about three miles east of Kyidaunggan station on the main line from Rangoon to Mandalay, and the Roads Committee having requested that geological opinion should first be obtained, Mr. E. J. Bradshaw was deputed to undertake the duty. The primary purpose for which the rock is required is that of road-surfacing metal for the maintenance of some 100 miles of the new Rangoon-Mandalay trunk road. Mr. Bradshaw concluded that the area is entirely suitable for the purpose. It contains two dominant rock types whose chief macroscopic difference is one of texture, each being a light grey biotite granite. He recommended that the quarry should be located at an outcrop of the finer variety of the rock, of which there is an enormous and practically inexhaustible supply, and which possesses the added advantage of being actually in sight and free from overburden. Although granite is not an ideal road metal, since both its 'toughness' and 'cementing value' are usually low, it nevertheless ranks fairly high and, in the present case, the fine-grained variety is sufficiently tough to be satisfactory and is probably more suitable for the purpose than any other rock to be found in the neighbourhood.

A site for a proposed dam in the Tungabhadra river, Bellary district, Madras, was selected by Mr. Vinayak Rao in March 1927. The site was again examined in October 1929 after borings and trenches had been sunk. The borings, 1½ inches in diameter, were taken down to a depth of about 83 feet, the rock pierced being mostly a hard chloritic schist with thin veins of calcite. Joints were observable down to a depth of about 50 feet. Samples of the cores have not yet been received, but the rock appears to be quite suitable for the foundations of a large dam. Further shallow trenches are required to show the contacts between the diabases, chloritic schists and other types of rock met with.

Tungabhadra Dam, Bellary District, Madras.

Gold.

The more important localities, between Pantin and Mamon (25° 35′ 10″; 96° 15′ 57″) in the Myitkyina district of Upper Burma where detrital gold is obtained by washing, were referred to in last year's General Report. In addition, the following places were recorded by Dr. H. L. Chhibber during the present season:—

Myitkyina District, Burma.

(1) The Uru river near Lonkin (25° 39′; 96° 22′),
(2) The small stream passing by the east Lonkin village,
(3) The island in the Uru river, opposite the village of Lasa (25° 38′ 57″; 96° 21′ 26″),
(4) The Mawsisa *chaung*, the first important stream crossed on the way from Lonkin to Hpakan (25° 36′ 38″; 96° 18′ 40″).

Gold is said to be washed from the sands of the Pettok *chaung* near Linlu (22° 46′; 94° 30′ 30″) and Pettok (22° 45′ 45″; 94° 31′ 30″) and also from the Shwegyin *chaung*, about 3½ miles south of Kyaukkedet (22° 57′ 30″; 94° 43′ 30″). These occurrences are on Sheet 84 J/9 of the one-inch survey of Burma, in the Upper Chindwin district. On Sheet 84 J/13 small amounts of gold are, according to Mr. B. B. Gupta, recovered from the following streams: the Ngakuaing, Auk, Myindingaw and Teon *chaungs*. The gravels do not appear to be rich as the workers only recover from 4 to 5 annas worth a day each. The metal is also found in the Thitsebingwe *chaung*, east of Taungbyingge (22° 50′ 30″; 94° 49′ 20″), the Nyaungthabye *chaung*, north of

Upper Chindwin and Shwebo Districts, Burma.

Pyaw (22° 55′; 94° 52′ 30″). The two latter localities are in the Upper Chindwin district and the remainder in Shwebo.

The occurrence of minute particles of gold was reported by Mr. Sondhi, in the last General Report, from the Irrawadian sand-rock in Sheet 84 J/14. In the north-eastern extension of the same series, covering Sheet 84 N/1, goldwashing is carried on in the villages of Kandawtha (22° 48′; 95° 1′ 20″), Ingyi (20° 51′; 95° 0′) and Kinbin (22° 56′ 30″; 94° 4′ 30″) during the rainy months when water is available in plenty for the purpose. Very fine particles appear to be disseminated throughout the sandy formation, but most of the washing is done in or near the Ingyi and Sawme *chaungs*. In the neighbourhood of Mezadaw (22° 57′; 95° 55′) in sheet 84 N/13, gold is washed in a small way from the same series but the size of the particles recovered here is larger.

Iron.

(*a*) Upper Chindwin and Shwebo Districts, Burma.

Heaps of iron slag were noticed in the following localities in the Upper Chindwin and Shwebo districts of Burma:—(1) three miles and two furlongs south of Kyaukkedet (22° 57′ 30″; 94° 43′ 30″) on Sheet 84 J/9, and (2) four miles south-east of Aikywa (22° 48′ 30″; 94° 53′) on Sheet 84 J/13. Mr. B. B. Gupta believes that the ores for the furnaces came from the local Irrawadian rocks which contain streaks of ferruginous sandstone as well as concretions of iron ore.

(*b*) Myitkyina District, Burma.

Three occurrences of iron ore in the Myitkyina district of Burma were described in last year's General Report. This year additional outcrops were observed by Dr. Chhibber:—

(1) On the left bank of the Sanhka *chaung* (92 C/6), where it is crossed by the Lonkin-Kansi road.

(2) Near Lama or Mabaw village (25° 42′ 22″; 96° 21′ 15″), forming a hard crust almost devoid of vegetation; a good section of the ore is seen in the Mabaw Hka, near its confluence with the Uru river.

(3) At Namshamaw (25° 45′ 31″; 96° 22′ 28″) where fantastic concretions of iron ore occur as strings and patches in the red earth.

(4) On hill '1380' (92 C/6), on the way to the Sanhka-hka-taungya, and also near a small marsh west of the north

Sanhka village on the way to the Sisu Bum; in the latter locality boulders of iron ore, in places lateritic in appearance, are associated with the Mabaw siliceous agglomerate, and are seen lying on the surface, where the red earth forming the matrix has been enriched in iron content and consolidated.

(5) In a small water-course in the neighbourhood of the old workings of Pangmaw, about 80 paces N.E. of the Pang Hka, where it is crossed by the Meinmaw-Namshamo path (92 C/6).

Northern Shan States, Burma.

Large quantities of iron ore were discovered in 1928 by the officials of the Burma Corporation, Limited, in the vicinity of Hsongke (22° 26′ 20″ ; 97° 37′) about 30 miles south-east of Hsipaw, the capital of the State of the same name in the Northern Shan States of Burma, and Dr. Coggin Brown visited the locality towards the end of the year with Mr. Hogan Taylor, the General Manager of the Corporation. The largest deposit is on Loi Leik Long, high ground upwards of 3,000 feet above sea-level some four miles E. N. E. of Hsongke as the crow flies. Similar but smaller deposits exist on other hills in the vicinity known to the Shans as Loi Leik Awn and Loi Kyawng respectively. By means of systematic pitting and tunnelling the engineers of the Corporation estimate that they have developed the following tonnages of ore :—

	Tons
Loi Leik Long	1,245,000.
Loi Leik Awn	246,000.
Loi Kyawng	75,000.
TOTAL	1,566,000.

On Loi Leik Long alone 235 pits, having a total depth of 6,384 feet, and 7 tunnels with a total length of 1,392 feet were made. After inspecting the more important of these Dr. Coggin Brown concluded that there are undoubtedly very large quantities of iron ore available, far exceeding in size any other deposit that he has seen in the Shan States.

The whole of the surrounding country is built up of Plateau limestone with its characteristic valleys of enclosed drainage and the ores, which are mainly limonite or mixtures of limonite and gothite, passing

occasionally into hard hæmatite, are of residual origin. In this they resemble the other occurrences of the Shan plateau.[1] In some of the pits and tunnels on Loi Leik Long the ore has not been bottomed and it is still uncertain whether, in addition to the normal deposits of residual origin, some replacement of the underlying irregular limestone floor has not taken place. From a chemical point of view the ores are of much the same composition as the better grades of ironstone from the Naungthakaw and other deposits at present under exploitation by the Corporation.

Southern Shan States, Burma.

The Palæozoic limestones of the States of Poila, Pangtara and Mawson in the Southern Shan States of Burma are generally covered with thick residual deposits of ferruginous clay in which pisolites and small concretions of iron ore of a limonitic character are often present. Hard surface accumulations of iron ore of no great extent occur, according to Dr. Coggin Brown, on the western slopes of the Mawson highlands, east of Te-thun (20° 58′ 15″ ; 96° 46′ 30″). Ironstone concretions of a larger size than usual occur in the surface deposits at the foot of the Taunggyi ridge about miles '95' and '96' of the Kalaw-Taunggyi road. (20° 47′ ; 97° 1′ 2″).

Jadeite.

Myitkyina District, Burma.

As a result of his work in the Jade Mines region up to date, Dr. Chhibber concludes that there are at least four jadeite dykes, containing very large reserves of this mineral, and intrusive into peridotites and serpentines. These he has named the Tawmaw, Meinmaw, Pangmaw and Namshamaw dykes respectively.

On the Tawmaw dyke, in addition to the well-known mines of Kadondwin and Dwingyi at Tawmaw itself, the three outcrops of Sarmamaw, Malinkamaw and Sanhka Hka-maw referred to last year are situated. It seems probable that the outcrop at Dareemaw (25° 43′ 56″ ; 96° 18′ 35″), visited this season, is situated on the same dyke. Another probable outcrop of jadeite lies north-west of Meinmaw (25° 44′ 24″ : 96° 20′ 40″), on the path which connects that village with the old Kansi-Tawmaw path, for several boulders of albite (*palun*) were found lying round the pit ; the Kachin miners apparently did not reach the jadeite underneath.

[1] Coggin Brown. 'Iron Ore Deposits of the Northern Shan States.' *Rec. Geol. Surv. Ind.*, LXI, pp. 180-195.

On the Meinmaw dyke are situated the outcrops of Shammomaw (25° 43′ 39″; 96° 20′ 40″), Meinmaw and Sharoinawngmaw (25° 44′ 59″; 96° 20′ 40″). This dyke runs north and south for about 1½ miles.

The third dyke with a N.W.-S.E. strike bears the outcrops of Pangmaw (25° 44′ 53″; 96° 20′ 54″), Wikhumaw and Kyobatmaw. The old workings of Pangmaw lie about 80 paces north-east of the Pang Hka, where it is crossed by the Meinmaw-Namshamaw path. Wikhumaw is about half-a-mile and the Kyobatmaw about ¾ mile north-west of it respectively. (Sheet No. 92 C/6).

Various outcrops of jadeite occur in the neighbourhood of Namshamaw (25° 45′ 31″; 96° 22′ 28″) but the active workings which bear the same name are situated near the confluence of the Namsai and Uru *chaungs*. Here jadeite boulders, which occur in the surrounding red earth, are sought for. From their appearance they seem to have undergone little movement and probably represent the disintegrated portion of the dyke, which has either still to be exposed or lies a little way further west.

A short distance further north are the deserted workings of Konpimaw where red jadeite used to be found, while about half-a-mile to the west of the same place, in and about a stream known as the Mawsitsit *chaung*, are further ancient workings from which two of the more valuable and semi-precious varieties of the mineral used to be obtained. These are known locally as *mawsitsit* and *kyettayoe*. The former is a beautiful dark green translucent stone and the latter is bright apple green in colour. Still more deserted workings exist at Wayutmaw, ¼ mile N.N.W. of those in the Mawsitsit *chaung*.

The following jadeite workings in deposits of Tertiary age are reported by Dr. Chhibber to exist in the neighbourhood of the village of Lonkin (25° 39′; 96° 22′).

(1) *Kademaw* (25° 39′ 17″; 96° 20′ 23″), near the Kachin village of Nmayang. Mining is carried on along the banks and in the vicinity of the Nmayang Hka. Quite recently the Chinese did some underground mining in the conglomerate.

(2) *Mawmaik-ak*. These workings are situated on both sides of the Nmayang Hka, between Kademaw and Masamaw.

(3) *Masamaw*. The workings of Masamaw (25° 39′ 33″; 96° 19′ 58″) adjoin the left bank of the Masa Hka. It is noteworthy that the workers are re-digging the old pits

and going much deeper. From the disposition of the Tertiary jadeite-bearing conglomerate here and elsewhere it is apparent that the greater portion of it must have been deposited by torrential streams descending from the adjoining hills.

(4) *Marawmaw.* This is a new locality worked for the first time this year. It lies about 150 yards N. N. W. of Marawgahtawng (25° 38′ 49″; 96° 19′ 36″). Of the total number of pits, about a thousand in all, about half had been dug in the crystalline schists instead of in the conglomerate—a striking confirmation of the need for a large-scale map of the jadeite-bearing area.

(5) *Mawsisa.* These workings lie mostly in the bed of the Mawsisa *chaung* which joins the Uru about ¾ mile south of Warong (25° 39′ 13″; 96° 21′ 15″).

(6) *Saungcheinmaw* marks some old pits at the confluence of the Saungchein and the Uru *chaungs.*

(7) *Ngopinmaw.* The workings are about ¼ mile north-east of Kademaw on the way to Sanhka (25° 41′ 8″; 96° 20′ 57″). They terminate south of the first tributary of the Nmayang Hka crossed by the path.

(8) *Sanhkamaw*, situated near Sanhka village. Numerous old workings exist in the area enclosed by the U-shaped bend of the Sanhka Hka, near its mouth.

Pangmaw II. There is one disused working about 6 furlongs N. N. W. of Mahok (25° 44′ 8″; 96° 22′ 53″) on the left bank of the small north and south bend of the Pang Hka.

The Tertiary jadeite workings in the neighbourhood of Kansi (25° 47′ 1″; 96° 22′ 48″) are listed below:—

(1) *Pangmamaw.* The old workings of Pangmamaw are in the Pangma Hka. In the past Kachins excavated the banks and the adjoining ground for boulders of jadeite in the Tertiary conglomerates. Dr. Chhibber was informed that some of the boulders found here were about the size of a buffalo, and it is therefore probable that they had not undergone much transportation.

(2) *Mutantumaw.* One of the main tributaries of the Pangma Hka is called the Mutantu Hka and gives its name to the workings situated in it.

(3) *Sarmhtanmaw.* The workings lie in a small tributary stream (of the same name) of the Pangma Hka, which joins the Uru river near Kansi.

(4) *Sanimaw.* These workings are in and along the Sani Hka. At the time of Dr. Chhibber's visit only one Chinaman was finding employment.

(5) *Shilamaw*, situated in the Shila Hka, a stream which joins the Uru below Kansi.

(6) *Aungbilemaw*, in the lower course of the Seintu Hka.

(7) *Hpalaimaw*, said to lie in the Hpalai Range.

The last two workings were not visited. During the present season both the Tawmaw Mines, Dwingyi and Kadondwin, have been worked, though only four claims were in operation at the former. The Kadondwin had previously been shut down for two years; the present exploitation is in the footwall with a working face about 21 feet wide, across which the jadeite dips to the east at 30°.

The sections observed both here and in the Dwingyi have revealed an important feature which throws some light on the mode of origin of the mineral. The jadeite occurs in the form of lenses in albite and three of these have already been worked out in the footwall of the Kadondwin. This strongly suggests the segregation of jadeite in the albite with which the original magma must have been supersaturated, since it forms by far the greater bulk of the dyke. In places it appears that jadeite was intruded subsequently into the albite with a band of amphibolite ('*shin*') between the two. It is noteworthy that wherever inclusions of amphibolite are seen in jadeite, a green colouring is developed in the latter near the contact. This is probably due to the absorption of iron and chromium from the former into the latter. The presence of chrome-epidote generally indicates the occurrence of richly-coloured emerald green jadeite in the vicinity.

In his report Dr. Chhibber has directed attention to the complete lack of systematic mining methods underground, resulting not only in dangerous workings but in considerable loss of the less valuable mineral. He believes that the cost of mining would be reduced and output considerably increased if the mine were properly timbered and if compressed air drilling and the use of dynamite were introduced under the supervision of a trained mining engineer.

The jadeite-cutting industry of Mandalay, Mogaung, etc., was inspected by Dr. Chhibber. As abrasives both imported carborundum and the powdered gem sand from Mogok are used in cutting and

grinding. Big boulders of jadeite are cut by the aid of coarse carborundum and large heavy bamboo bows fitted with steel wire, the latter worked by two coolies. Small pieces of jadeite are cut with a sharp-edged bronze disc and fine carborundum. The shaping is mostly done by grinding on flat slabs made of powdered gem sand and gum. Finished articles are polished on small slabs of stone of very fine texture or on brass and leather plates. Holes are bored in beads with a small Archimedean drill tipped with a high grade Brazilian diamond point. The making of jade bangles and jade carving is mostly confined to China, but a few Chinese are thus employed in Mandalay.

Kaolin.

Shwebo District, Burma.

Mr. B. B. Gupta reports the occurrence of small pockets of kaolin of no commercial value in Irrawadian rocks, two furlongs W.S.W. of Taungbyinnge (22° 50′ 30″; 94° 49′ 20″), Shwebo district, Burma.

Lead and Silver.

Northern Shan States, Burma.

During his survey of Sheets 93 E/7 and E/11 of the Northern Shan States, which included parts of North Hsenwi and Mongmit, Mr. G. V. Hobson found along a major strike fault mineralisation in the form of barytes and hæmatite in the Pangyun group of rocks and of galena and zinc blende in favourable horizons in the Chaung Magyi series. At one prospect values of 6·33 per cent. of lead, 8 oz. 9 dwt. 20 grs. of silver per ton, and 3·31 per cent. of zinc were found in a sample taken across a width of 11 feet 2 inches. Such a grade of material does not, however, constitute a payable ore in this inaccessible region. Mr. Hobson was not impressed with the economic possibilities of a magnesian limestone horizon in the Chaung Magyi series, but thought that the evidence of the extent of work done by the Chinese on Hill '6433' was such as to warrant a more detailed examination of this locality, in the event of any improvement in transport facilities in this region. This opinion is given in spite of the failure of an earlier attempt to open up the deposit on this hill.

Mawson State, Southern Shan States, Burma.

During his survey of Sheets 93 D/9 and D/13 of the Southern Shan States, Dr. Coggin Brown made a preliminary examination of the lead and silver bearing region which lies mainly within the Mawson State. The area stretches from about the latitude of Kyauktap (20° 51′;

96° 48′ 30″) in the south to the borders of Lawksawk (about latitude 21° 0′) in the north and from the neighbourhood of Tethun (20° 58′ 15″: 96° 46′ 30″) in the west to the edge of the Mawson highlands on the east (long. 96° 55′). Old mine workings and scattered dumps of ancient lead slags occur at intervals within these limits over an area of approximately 50 square miles. As early as A. D. 1426, according to the Upper Burma Gazetteer, Mo-hnyin Mintaya, King of Burma, collected miners from Mogaung and sent them to Mawson and it is certain that primitive mining and metallurgical operations—particularly the extraction of silver—were carried on for centuries until their extinction after the annexation of Upper Burma in 1886. Short earlier references to the industry occur in papers by F. Fedden, E. J. Jones and C. S. Middlemiss.[1]

According to Dr. Coggin Brown the highlands of Mawson form a broad anticline, complicated by smaller subsidiary folds and also probably fractured in a direction parallel to the strike which is approximately N.-S. The western limb of the fold is made up of argillaceous limestones often with a characteristic 'augen' structure passing into calcareous shales with interbedded shales, slates and mudstones. The whole series shews signs of intense crushing and shearing. To this group of rocks the name Orthoceras beds has been given owing to the prevalence in them of that cephalopod.

In Eastern Mawson, however, which comprises the other limb of the anticline, thick limestone horizons occur, separated by a few strongly marked, arenaceous horizons. The whole country is buried under a thick mantle of residual clay and the true relationships of the two rock groups are not at present apparent. (*See* page 94.)

The lead ore deposits are largely though not entirely confined to the latter group (the Mawson series). The surface distribution of the old workings has been well summarised by a recent writer, W. H. Rundall, as follows[2]:—

'There are several more or less parallel ore-bearing zones, if the extensive but sparsely and sporadically mineralised north-and-south channels of brecciated and partly decomposed limestone, several hundreds of feet in width, may be so denominated—which stretch for many miles, and are easily traceable during the dry season, after the grass has been burnt, by the numerous small dumps of the many workings that remain to some extent intact, and by the depressions formed after the workings have collapsed.'

[1] F. Fedden : *Select. Rec. Govt. India.*, Vol. XLIX, p. 39. E. J. Jones : *Rec. Geol. Surv. Ind.*, Vol. XX, pp. 191-194. C. S. Middlemiss : *Gen. Rep. Geol. Surv. Ind.*, 1899-1900, pp. 122-153.

[2] W. H. Rundall : *Trans. Inst. Min. & Met.*, Vol. XXXVII, pages 27-49.

Dr. Coggin Brown found it impossible to trace these bands of old workings accurately on the only available map and has suggested the preparation of one on a larger scale in the hope of being able to do so later. Amongst the many thousands of ancient pits the following more important groups may be mentioned[1] :—

(*a*) The Kyeindaw band about 1⅜ miles east of Kyeindaw village (20° 56′ ; 96° 46′ 15″).

(*b*) The Ngwedaung, Pongkaing and Chaungyegaung workings, a little further east.

(*c*) The Gwekot-Pakin workings and the Ngwe-cho, Singaung extension. Gwekot (20° 59′ 45″ ; 98° 47′), Pakin (20° 58′ ; 96° 48′).

(*d*) The Taung-ye Twinzu workings *en echelon* to the south-east of the Ngwe-daung-Kyeindaw line in much the same way as the Gwekot-Pakin occurrences are to the north-east of it.

(*e*) The Siset-Mogaung-Kyauktaga belt. (Siset : 21° 0′ ; 96° 49′ 30″).

(*f*) The Myin-yi-ein workings, east of '△ 4860.' (20° 57′ 30″ ; 96° 49′ 10″).

(*g*) The Chaungmyaung-Bawdwinja-Seinji band and its extension. Seinji is close to Tadagon (20° 57′ 45″ ; 96° 50′) on the west.

(*h*) The Tantape Channel (20° 59′ 15″ ; 96° 52′ 10″).

Modern mines have been opened up at Bawdwinja, near Ywahaung-gyi (20° 58′ 45″ ; 96° 50′) and at Bawzaing (20° 56′ 20″ ; 96° 50′ 20″). The former has developed a flat pipe of ore-bearing clay in limestone, of comparatively small and exceedingly irregular section. At Bawzaing an irregular pipe with a decided pitch to the south is exploited. It appears to lie in a brecciated zone of limestone with minor arenaceous rocks and to consist mainly of ore-bearing clay containing very numerous irregular limestone blocks of all sizes. Decomposition, according to Dr. Coggin Brown, has been very profound and the deepest workings, some 500 feet below the surface, have not yet passed through the zone of superficial alteration. With the exception of certain galena-barite veins and the occasional occurrence of disseminated galena in limestone, or an insignificant

[1] Many of these localities are not shown on the 1-inch map.

veinlet of galena with calcite or quartz, all the deposits available for study are greatly modified by surface weathering.

The ore-bearing clay, won alike by the ancients and by the modern miners, is a soft, pulvurent earth when dry, various shades of brown and reddish-brown in colour, often with very fine laminæ of a still paler tint. It recalls a dry alluvial clay and becomes plastic and unctuous when wet. Through this irregular nodules of galena are distributed, varying in size from that of coffee beans to exceptionally large masses weighing one or two hundredweights. Their cracks and crevices nearly always carry anglesite or cerussite, but usually the latter mineral. Their corroded outer skins are often observed passing into cerussite and a good deal of this mineral in fine, pulvurent, earthy forms is obtained by washing the ore-bearing clay.

Dr. Coggin Brown's preliminary investigations have shown that there is an intimate connection between the lines of old workings and certain well defined horizons of soft sandstones and sandy shales, which are interbedded with the Lower Palæozoic limestones of Mawson. While it is not unusual to find old workings sunk on fissures and cracks in the limestone itself, the great majority of them enter the sedimentary horizons and appear to have found ore in them or in the particular limestone band which underlies them.

Bearing in mind the tendency of the limestones of the Shan States to form residual clays and granting the existence of a group of rocks like those of the Mawson series, already fractured and folded extensively, and sporadically impregnated with finely divided sulphides, as well as containing galena-calcite veins, we see that an unsuitable system exists particularly liable to corrosion and decay under local climatic conditions– a system in which it is only reasonable to expect that much of the lead ore would migrate, subside and finally accumulate in the irregular manner which mining operations have shown these deposits to possess. A redistribution of the materials may also have taken place along pre-existing pipes, channels and solution cavities of the underground circulation system.

The lead ores of Mawson are singularly free from zinc or copper and the silver content varies from 10 to 40 oz. per ton of lead. There is little in common between them and the great Bawdwin deposits. To some extent they are of metasomatic origin, for the galena occurs at times disseminated in limestone. That the rock openings in which mineralisation has taken place are partially determined by the prevailing joint system, appears to be certain from the characteristic

form of many of the ore nodules, but whether the major channels of ore deposition when found at deeper levels than have been opened up to-day will prove to be related to the larger joint system, or dependent on fault fissures, has still to be determined. Like most other deposits of their class the ore bodies seemed to Dr. Coggin Brown to follow definite 'runs' and the correct interpretation of these demands a thorough knowledge of local geological structure. Finally, the disposition of the ancient workings leads to the suspicion that impervious overlying beds of shale and similar rocks, have had a considerable influence on the migration of ore-bearing solutions and consequently on ore deposition.

Limestone.

Almost unlimited quantities of limestone occur in the area mapped by Dr. Chhibber in the Myitkyina district of Burma.

Myitkyina District, Burma.

On sheet 92 C/5 the Hpalai range (4,004 ft.) and the Chaobadu Bum (3,757 ft.) are formed of this rock. On sheet 92 C/6 the Bumrawng and the Paphuk Bums are important limestone hills, the latter being quite accessible and only about ½ mile west of the 7th mile on the Kamaing-Nanyaseik road. A small outcrop of limestone about ¾ mile west of the bridge over the Hkakon Hka on the Migaung-Kamaing road is being quarried at present. It is being burnt for lime to be used as a fertilizer on the Sahmaw Sugar Estate. Five kilns dug in the banks of the stream were being worked at the time of Dr. Chhibber's visit.

Magnesite.

A deposit of magnesite covering some 2,000 acres in the Chettichavadi *jaghir* of the Salem district, Madras, was investigated by

Salem District, Madras.

Rao Bahadur M. Vinayak Rao. The area, which had been previously reported upon in part by Mr. C. S. Middlemiss, lies about 3 miles north of Salem junction. The rocks at the southern extremity consist of a highly garnetiferous hornblendic gneiss approaching a syenite, some pyroxenites, norites and other members of the Charnockite series. These appeared to Mr. Vinayak Rao to be intrusive into the magnesite-bearing rocks. A band of enstatite was found on the top of a low hill at the southern extremity, and several other bands of this rock appeared further north. Pyroxenites were observed at the eastern boundary of the *jaghir*, while

to the west were gneisses and granites. Magnesite occurs in veins of varying width. This width increases with depth, and the veins in places form a regular stockwork. The whole area is impregnated with magnesite of good quality.

Manganese.

Dhalbhum, Bihar and Orissa.

Recently, deposits of manganese have been opened up on the ridge between Mirgitanr (22° 44′; 86° 29′) and Basadera (22° 45′; 86° 30′), and on the hills east of the latter village, in Dhalbhum. Dr. Dunn found that the manganese occurs as lenticular masses interbedded with phyllites. There is a large number of such occurrences in these hills, in addition to a considerable amount of debris. The majority of the beds rapidly thin out and do not attain any considerable size.

Mica.

Myitkyina District, Burma.

Mica which is mainly colourless but which in places shows a brownish tinge was found by Dr. Chhibber in some quantity on the north-eastern slopes of the Bumrawng Bum, about the level of the 1,250-foot contour, *i.e.*, just above the pass between the small hill about 1¾ miles N.W. of Hkumgahtawng (25° 31′ 42″; 96° 36′ 3″) and the Bumrawng Bum (2,476). Books of mica about half an inch thick and with a diameter of over four inches were seen widely scattered on the weathered surface on the left bank of a stream flowing N.N.E. and forming the headwaters of the Noidaw Hka. It is associated with a medium-grained pegmatite with a micrographic intergrowth of quartz and felspar. Dr. Chhibber had a small pit dug to a depth of about 6 feet and found that mica continued to that depth; some of the books are described as measuring more than a foot in diameter. Specimens of muscovite, apparently derived from the neighbouring granite hills, were also collected from the Kathan Hka, near Sakaw (25° 29′ 53″; 96° 38′ 43″).

Petroleum.

Lower Chindwin District, Burma.

In the last annual summary of the work of the Burma party a list of localities in the Lower Chindwin district of Burma was given where oil seepages had been found by Mr. B. B. Gupta, in addition to those enumerated in Sir Edwin Pascoe's Memoir on the

Oil Fields of Burma, (*Mem. Geol. Surv. India*, Vol. XL, Pt. 1, pp. 144-145). During field season 1928-29, Mr. Gupta found another seepage in the extreme north of the district in a tributary of the Michaungdwin *chaung*, about one mile and six furlongs west of the village of the same name (22° 48′ 30 ; 94° 41′).

Pyrites.

Northern Shan States, Burma.

While working in the Northern Shan States of Burma Mr. Leicester examined an occurrence of iron pyrites in a small stream (Sheet 93 E/7, Long. 97° 23′ 20″; Lat 23° 22′ 23″) flowing southwards into the Nam Ping, on its left bank, one mile due west of Man Sak-ka village. The sulphide occurs as fine crystalline aggregates scattered throughout a large vein of white quartz. The quartz vein is associated with a small intrusion of amphibolite into the slates of the Chaung Magyi series about one mile south of the granite boundary. The quantity of pyrites is small and Mr. Leicester considers that the occurrence is of little or no economic importance.

Shwebo District, Burma.

Mr. V. P. Sondhi reports that iron pyrites is associated with coal in the Kodaung *chaung* (22° 54′ ; 95° 57′ 30″) Shwebo district, Burma, and is also found as small nodules disseminated in some of the sandstone beds in the same stream. In the Padauk *chaung* (22° 52′ ; 95° 52′) pyrites occurs in a sandy shale.

Ruby, Spinel, etc.

Myitkyina District, Burma.

Rubies were apparently collected in the past in the neighbourhood of Nanyaseik (25° 37′ 11″; 96° 35′). The industry is dead at present but several of the old mining centres were visited by Dr. Chhibber around Manawmaw (called 'Lepyinmaw' by the Shans. Sheet 92 C/10). There are two kinds of workings, shallow pits, and open cuttings along the stream bank. The former are by far the more numerous of the two but they have been partly filled with earth and are overgrown with jungle. Dr. Chhibber was informed that the maximum depth of a pit was about seven yards but that generally the depth varied from 3 to 12 feet.

Two old pits were re-dug at Manawmaw and the following sections observed :—

A. Overburden, loam ; 5 feet 6 inches.
Gem-bearing gravel or '*byon*' ; 1 foot 6 inches.
Decomposed granite.

The water level was six feet four inches from the surface.

B. Overburden, loam ; 3 feet.
Gem-bearing gravel ; 2 feet.
Weathered lateritised granite.

The *byon* contains quartz, felspar, phlogopite, chlorite, calcite, spinel and ruby. The coarser the *byon* the bigger is the size of the gems.

Numerous old workings were seen along the banks and in the neighbourhood of the Shayat Hka, a small stream issuing about half-a-mile N.E. of the deserted village of Nawhkum (25° 39′ 2″, 96° 32′ 41″). In another small stream, a little east of the Shayat Hka, locally called the Kyan Hka, a tributary of the Kammo Hka, unmarked on the map (92 C/10), many old pits were observed in the bed, banks and vicinity. Old workings are to be seen at intervals along the left bank of the Kammo Hka and continue down to the neighbourhood of Padaw (25° 37′ 54″; 96° 33′ 51″). Old workings ('*mawgyi*') are said to occur along the upper course of the Kammo Hka above the deserted village of Nawhkum (92 C/10), but have been deserted for 25 years.

Salt.

Myitkyina District, Burma.

Twelve salt springs have been recorded by Dr. Chhibber as occurring in the area mapped by him in the Myitkyina district of Upper Burma during the past field season. At two of these localities brine is boiled to manufacture salt. The more important is Mabawmaw (25° 42′ 22″; 96° 21′ 15″; marked 'Lama' on Sheet 92 C/6). Two important springs lie close to the bed of the Mabaw Hka and a third lies in a tributary of the former. The main spring occurs on the right bank of the stream and is about ¼ mile N.W. of the village ; it is a shallow well, lined with serpentine boulders, nearly 11 feet deep and over 9 feet wide. At present all activity is centred round the first spring. A gallon of brine, collected here in December, 1928, was found to contain 2,867·82 grains of solid

residue which on analysis in the Rangoon laboratory yielded the following results :—

	Per cent.
Sodium chloride	78·29
Potassium chloride	14·21
Calcium chloride	6·38
Magnesium chloride	0·70
Calcium sulphate	0·62
Insoluble matter { Inorganic	0·08
Insoluble matter { Organic	traces.
TOTAL	100·28

Four furnaces, oblong in shape, were being worked by Kachins at the time of Dr. Chhibber's visit. Brine is generally heated in iron cauldrons over a furnace. Boiling is carried on day and night and the yield of one furnace in 12 hours was stated to be 5-6 *viss* or about 20 lbs. The salt is sold at the rate of four annas a *viss* and supplies all the local demand in the Kachin hills. The main cost of production besides that of labour is the price of the cauldrons. Firewood is obtained free from the jungle. These springs are thought to lie along a fault, forming the western boundary of the Mabaw siliceous agglomerate.

The second locality where salt is boiled is marked 'Kyum Hka' (25° 41′ 54″; 96° 23′ 51″)—'salt water'—on Sheet 92 C/6. This spring is situated in the Tertiaries in the bed of a small stream. It has been converted into a small well, about five feet deep, surrounded by a bamboo structure. Sulphuretted hydrogen escapes but not so briskly as in the case of Mabawmaw. A large number of volcanic boulders were seen in the neighbourhood. Only one furnace is worked here but at the time of Dr. Chhibber's visit operations had been suspended on account of the destruction of the shed by a recent fire.

Jhelum District, Punjab.

Three or four springs of concentrated saline water, heavily charged with sodium chloride and a small amount of dissolved hydrogen sulphide gas, occur near Kalra at the foot of the small Nummulitic inlier of the Bakrala hills, Jhelum district, Punjab. Many tons of salt must be annually brought up to the surface by the combined agency of these springs from a deep source, probably a concealed pocket of salt marl. Besides the chloride, sodium sulphate is also present in smaller quantity. The brine is appreci-

ably below saturation-point but the specific gravity of the liquid, collected in the pool near the springs, is high. The springs are 33 miles N.N.E. of the Khewra salt deposits.

Warcha, Salt Range, Punjab.

Mr. E. R. Gee was deputed to pay a short visit to Warcha, Salt Range, Punjab, to advise the authorities of the Northern India Salt Revenue Department regarding the position of a suspected fault which might interrupt their mine-workings to the south-west. During a previous visit to that area in October, 1926, Mr. Gee had noted the surface outcrops in the vicinity of the mine and had come to the conclusion that, in addition to the faults already proved in the dip workings, a large fault traversed the area to the south-west. A large-scale topographical map, having been made in the meantime, it was now possible for him to demarcate fairly accurately the position of this fault on the surface and its relation to the present workings of the salt-mine. The fault, which proves to be a large upthrow to the west, follows a general southerly course, and is well-exposed in the cliffs of Permian limestone at the top of the slopes above Rukhla village. The zone of shattering in these cliffs is at least 30 yards wide. Further down the slopes the exact position of the fault is obliterated by subsequent slips of the limestones. The dark purple clays and purple-red sandstones, apparently of the Speckled Sandstone series, which overlie the salt marl above the present mine, can be traced down the slopes towards Rukhla village on the east side of the fault; on the west side they crop out again well up the stream-course which drains the slopes above the village. In this stream-section gypseous red marls, representing the uppermost horizons of the salt marl, crop out beneath these Speckled Sandstone beds, and the suggestion was made to prove these salt-bearing beds on the west side of the fault by an adit located in the vicinity of this stream-course below the outcrop of these gypseous beds.

On the surface, the fault appears to run from 100 to 300 feet west of the most westerly chamber, No. 6, of the old British workings of the mine, so that, depending on the hade of the displacement, it was assumed that it should be met with at no great distance from this chamber. An old drift existed running for about 75 feet W. 30° S. from No. 6 chamber, and here the seam of salt and marl showed a distinct change of dip towards the fault. This drift was blocked up at the time of Mr. Gee's visit, but it has since been cleared. The end of the drift bears evidence of the

fault having been struck. This proves fairly conclusively that the fault will be found to cut off the workings not far to the west of No. 6 chamber and, being of a large throw, it will probably prevent further development to the west.

Kalabagh, Mianwali District, Punjab.

In conjunction with his visit to Warcha, Mr. E. R. Gee was asked to include Kalabagh in order to advise regarding the salt deposits of the south side of Kalabagh hill, just north of Kalabagh village, and to select sites for exploratory drifts for the purpose of proving these deposits. The salt marl with numerous outcrops of rocksalt is exposed in the hillside just north of Kalabagh village dipping steeply in a direction N. 20°-30° E. After crossing the stream near No. 19 guard-post, in which locality the beds are more highly disturbed, the salt-bearing beds swing round slightly to the west, and are again exposed in the area around No. 20 guard-post, dipping very steeply to the north. The uppermost strata include *grey and dark purple, hard clays with grey dolomite bands accompanied by irregular bands of white gypsum,* closely resembling the uppermost beds of the Salt Marl series in certain parts of the Punjab Salt Range to the east. Beneath these strata dark red and purple-red clays, including seams of rocksalt, comprise the remainder of the exposed portion of the series. The base of the salt marl is hidden by the river gravel and alluvium of the plains to the south-west. The salt marl, as exposed in these sections, might be roughly divided into three zones:—

I. An uppermost zone, probably about 300 feet thick, including relatively thin seams of rocksalt alternating with marl. The salt is largely white or pinkish in colour, but, particularly in the upper horizons, bands of grey-coloured salt also occur.

II. A middle zone, several hundred feet thick, consisting of large outcrops of pinkish-white rocksalt with marls.

III. A lower zone of red marls with doubtful seams of rocksalt.

The seams of Zone II appear to offer the greatest possibilities for exploitation, the outcrops suggesting that a number of thick seams of good quality rocksalt are included within this zone. Lateral variation must be expected, as in the case of the seams of the present Kalabagh mine. The strata of Zone I had been

tested by a drift in the slopes above guard-post No. 18, but the seams of rocksalt struck in this drift were of insufficient thickness to be, by themselves, profitably extracted.

The seams of Zone II crop out in the steep hill-slopes just behind Kalabagh village, and westwards around guard-posts Nos. 18 and 20. The red marls of Zone III form the foothills below, just west of the village. These marls have been largely covered by river alluvium for a short distance west of Kalabagh, and it is probable that, at the time when the sand and boulder deposits were laid down, any seams of rocksalt which were exposed at the surface were dissolved in the vicinity of the surface and have become hidden from view. The absence, therefore, of exposures of any large seams of salt does not preclude the possibility of their occurrence in depth beneath the covering of marl. Several small outcrops do occur within these foothills, and salt has apparently been mined on a small scale at one locality. It is quite possible, therefore, that at a depth below the weathered strata, seams of workable rocksalt would be met with in the marls of this lower Zone III. The existence, however, of good seams of salt within Zone II is much more obvious; Mr. Gee therefore suggested that these beds north of Kalabagh village should first be proved by an adit running approximately N. 30° E. Further west the equivalent beds, outcropping near No. 20 guard-post, should be proved by an adit running in a northerly direction, driven, if possible, at a low-level below the solution-holes of that area. Provided that workable salt deposits of sufficiently large extent are met with in these areas, a low-level tunnel might be driven beneath the foothills for the purpose of direct transport to the railway at the edge of the plains. It is quite possible that workable seams of rocksalt would be met with in such a low-level tunnel within Zone III of these foothills. Mr. Gee, however, is doubtful whether the proving of such seams as do exist would alone justify such an expensive proposition.

The conclusions arrived at by Mr. Gee are in general agreement with those of Dr. J. A. Dunn, who visited the area in January 1926.

Silver (see Lead).

'Soap-Sand' ('*Sapaya*') and 'Soap-Water'.

'*Soap-Water.*'—Springs highly charged with alkalies were observed by Dr. Chhibber to occur in the bed of the Sapya Hka (Sheet 92 C/7), especially near its junction with the Hwehka Hka, in the Myitkyina district of Upper Burma. The water is used locally to launder clothes. The alkalies have probably been derived from the felspars of the grano-diorite exposed immediately on the west.

Myitkyina District, Burma.

Mr. Sondhi reports that the slushy mud and water, which ooze from the mud springs east of Kin-u (22° 46′; 95° 37′ 23″) in the Shwebo district of Burma, are impregnated with alkali salts, which are deposited on evaporation of the water. These and the efflorescent salts that encrust the surrounding surface are collected and are refined by evaporating their filtered solutions. The refined product is obtained either in semi-crystallised cakes or in powder, and is an article of toilet; the unrefined sand is used to launder clothes.

Shwebo District, Burma.

Spinel (see Ruby).

Sulphuretted Hydrogen.

Springs charged with sulphuretted hydrogen were noticed by Mr. B. B. Gupta in the northern tributary of the Baingbin *chaung*, about three miles and six furlongs in a line 15° S. of W. from Kin (22° 46′; 94° 42′), in the Lower Chindwin district of Burma.

Lower Chindwin District, Burma.

Salt springs heavily charged with sulphuretted hydrogen were noticed by Dr. Chhibber in the Mabaw Hka and the Kyum Hka (25° 41′ 54″; 96° 23′ 51″), in the Myitkyina district of Burma. (See 'Salt'.)

Myitkyina District, Burma.

Talc.

Dr. Dunn reports that talc deposits occur at intervals along the Singhbhum Copper belt in Dhalbhum. The talc has resulted from the alteration of igneous rocks. These deposits were excavated at a very early period by people who made neat round shafts off

Dhalbhum, Bihar and Orissa.

which galleries were driven; the present day villagers, on the other hand, work in a very haphazard fashion.

Tin.

Amherst District, Burma.

At Kunhnitkway (Sheet 95 E/13. Lat. 97° 51′ 36″; Long. 15° 48′ 22″), in the Amherst district of Burma, Mr. Leicester examined an occurrence of black cassiterite in a small pegmatite vein which is mined during the monsoon. The vein measures two feet across at the thickest part and follows the bedding planes of the country rock which consists of sandy shale and sandstone. The strike is N. 38° W., and the vein dips south-westwards at 70°; thinning out in places it appears again farther on in the same line. The pegmatite is much kaolinised and the extraction of the cassiterite, in which the rock is rich, is not difficult. Unfortunately, however, the vein being narrow and the dip steep, it will soon be unprofitable to work it on account of the increasing overburden. No prospecting has yet been carried out to ascertain if the talus on the slopes below the vein contain any payable quantity of ore.

Water (see also Engineering Questions).

The waterless tracts of Burma; Shwebo District.

In August 1926, Dr. J. Coggin Brown undertook to supply such geological information as is available on the problem of obtaining underground water supplies in the waterless tracts of the 'Dry Zone' of Burma, for domestic and agricultural purposes. The General Report of that year contains a summary of the situation in the Myingyan district by Mr. C. T. Barber. In the report for 1927 Dr. Coggin Brown's views on the question in the districts of Thayetmyo, Kyaukse, and Mandalay are referred to. In the 1928 report, Mr. Sondhi dealt with the Lower Chindwin district and Mr. Bradshaw with parts of Sagaing while Dr. Coggin Brown described prevailing conditions in Magwe, Meiktila, Minbu, Pakokku and Yamethin.

The waterless tracts of the Shwebo district, situated in Sheets 84 N/1, N/5, N/9 and N/13, were visited by Mr. V. P. Sondhi in the course of the geological survey of these sheets, during the season 1928-29. Most of the area covered by these sheets is in the catchment of the River Mu which runs towards the south approximately through the centre of its broad shallow valley. All the

waterless tracts dealt with are scattered over this catchment, on both sides of the river. The geology of the area is very simple; alluvium extends from 12 to 16 miles east and west of the river, and beyond it the underlying Irrawadian series is exposed. The Irrawadian series here consists of a deposit of incoherent sand containing a variable proportion of clay.

The alluvium is mostly derived from this deposit and is likewise of a sandy nature, with a greater proportion of clay, yielding a sticky soil in places. The lithology of the Irrawadians changes, sometimes rapidly, because of changes in the proportion of its clay content, and the surface exposures of the series do not show any definite bedding or sorting of the material.

The water table in the area is not low, and is easy of access by hand-dug wells, but the yield of the wells is generally very small on account of the slow rate of seepage into them. The unsorted sand-rock has a low permeability due to the fact that the smaller particles of sand and clay choke the inter-spaces between larger grains and thus obstruct the flow of water therein. The series, moreover, is known to contain sporadic occurrences of soluble alkali salts, and these raise the usual difficulties, common to the rest of the 'Dry Zone' of Burma, in dealing with questions of underground water supply. Efflorescences of salt were observed and brine wells reported at various localities in the course of the survey work, but the most outstanding example is the existence of mud springs west of Kin-u which emit a rich solution of alkali salts. As there is no evidence to show whether sub-surface conditions of low permeability and saline character would improve with depth, tube wells cannot be recommended with confidence in the area.

The waterless tracts of the Kin-u township, lying in the sheets surveyed, namely Ngayogyi, Sawgyi, Ba-o, and Kin-u, are governed by very similar geological conditions; they are situated on alluvium of a semi-permeable nature, which overlies and is derived from the sandy Irrawadian series. Ngayogyi is half a mile from the Shwebo canal and three miles from the River Mu, and is not very high above the river level. The water table cannot be very low here but the difficulty is experienced of a restricted inflow of water due to the low permeability of the deposit.

The Sawgyi tract lies about six miles east of the Ngayogyi tract, over alluvium of a more sandy type. The chances of a

successful tube well are exceedingly poor, but the conditions here are expected to improve when the old Mu canal is remodelled.

The remarks on the Ngayogyi tract apply to the Ba-o tract with equal force, except that the water table is lower here, as the tract lies further east of the Shwebo canal.

The Kin-u waterless tract, though situated on the alluvium, is very near the Irrawadian sands and the salt mud springs. In the month of January, 1929, the water table was from 6 to 9 feet below the ground surface in different wells in the town. In the month of May, *i.e.*, in the early dry season, the water table fell by about 6 feet. These measurements, however, cannot be taken as normal because of the abnormally heavy rain in the preceding rainy season. The water table is generally easy of access in years of normal rainfall but the intake of the wells is very low and the yield is consequently very small. Tube wells are not expected to succeed here on account of the salt springs and the low permeability of the country rock. The yield of the hand-dug wells in the town is likely to improve when the old Mu canal, which runs just east of it, is remodelled, or when a large tank, now under consideration, is constructed east of the town.

Of the waterless tracts of the Kanbalu township, situated in the area under discussion, Sudat lies on the alluvium so close to the underlying Irrawadian that the question of underground water is confined to the latter series. The Kyauksegan and the Bugon tracts lie directly over the Irrawadian series, and the sinking of a tube well is not recommended.

The village of Zigon (Tantabin railway station) lies over sandy alluvium, and wells 36 feet in depth contain about three feet of water ; when this is drawn off, however, they recoup very slowly. As similar beds are expected to continue downward the success of a tube well is very doubtful. When the old Mu canal is remodelled this village may also be benefited as it lies west of the canal, which is also the direction of flow of the underground water. The same remarks hold good for Nagabaw.

The Meoh and the Malwe tracts of the Ye-u township in Sheet 84 N/5 form a single tract lying over alluvium. The water table is usually within ten to twelve feet but the rate of intake of the wells is very low. The Shekadaw, Nyaungsigon, and Taze tracts of the Taze township in the same sheet also suffer from the same circumstances.

Although the conditions cannot be called favourable for tube wells it might be worth while to test one of the tracts in this sheet with a deep boring, in order to ascertain the true quality and quantity of the ground water available. The results obtained in one case, favourable or otherwise, would have much bearing on the problem in other tracts under similar conditions. For this purpose one of the tracts in this sheet is to be preferred as it forms the basin of the Mu valley, and the alluvial blanket here is likely to be thick.

The Kaduma, Zebauk, Ywathitkon, Kyaungthiaing, and Ledi tracts of Sheet 84 N/1 lie over the alluvium very close to its junction with the Irrawadian series. Taken together they form a single area with similar geological features in which tube wells are almost out of the question.

Bassein, Burma.

At the request of the Sanitary Engineering Branch, Public Works Department, Burma, this department has given geological advice on the possibilities of obtaining tube well water supplies at Pyu in the Toungoo district, at Talakwa in the Bassein west township and at Waw in the Pegu district.

Prome Civil Station, Burma.

The Public Works Department, Burma, commenced to sink a well in one of the valleys of the Prome Hill civil station. In an adjoining valley was a well which gave a supply of water and from this example it was thought that water would be found in the position selected for the new well. When the new well had been sunk 60 feet, the excavation for the last 10 feet was through soft, quite dry rock and, as the prospect of obtaining water appeared remote, this Department was asked to examine the site and to give an opinion on the prospect of obtaining an adequate supply of water at a reasonable depth. Mr. E. J. Bradshaw was deputed to undertake the enquiry.

Prome Hill civil station is immediately south of the town of Prome and forms part of the steep ridge on the left bank of the River Irrawaddy. West of the civil station rocks of the Upper Prome series crop out in the river; Prome hill itself consists of rocks of the 'Fossil Wood Group.' These formations have been described by Theobald and in greater detail by Murray Stuart, who mentions that the general character of the Upper Prome series, which consists of alternations of massive and shaly sandstones

and shales, is softer than that of the underlying Lower Prome series, the outcrops being characterised by lower hills than those formed by the beds of the Lower Prome series. The 'Fossil Wood Group' is classed by Murray Stuart with the Irrawadian series and here consists of a mixed assemblage of shales, sands and subordinate conglomerates, passing upwards into yellow sands which are in turn overlain by the gravels of the older alluvium. At Prome Hill civil station the visible rocks all belong to the 'Fossil Wood Group.' The beds dip to the N.E. at 30° and overlie, unconformably, beds of the Upper Prome series, which probably dip in the same direction but at a steeper angle. A point to note is that west of the civil station the beds which form Prome hill do not crop out in the river. The geological structure is such that except at very great depth the source of supply of any underground water in Prome hill is the rain which, for a limited part of the year, falls on the small catchment area constituted by the hills themselves.

The record of the well showed that from 0—5 feet vegetable earth was penetrated followed from 5—20 feet by yellow sandy clay. From 20—36 feet the rock was yellow sand and thence to the bottom of the well at 63 feet firm dry shale and clay mostly light blue in colour. Information was given that during a period of 13 hours the percolation was only from 6 to 9 inches, which works out to between 200 and 300 gallons of water. This water presumably comes from the lower part of the bed of friable sand-rock between the 20 and 36 foot levels.

In Mr. Bradshaw's opinion there is no prospect of this well's obtaining an adequate supply of water at a reasonable depth. A deep and costly well might strike sufficient water but it should be borne in mind that the supply would not be artesian, and that, as a general rule, the cost of raising water from a deep tube well is considerably greater than the cost of pumping water to the same height in the ordinary way. There is an unlimited supply of pure water to be obtained in the low ground north and east of Prome hill. The cost of drilling a comparatively shallow well in the low ground would be a great deal less than that of drilling an abnormally deep well in the hill itself. The supply of water in the low-level well is assured; in the deep well it would be problematical. In both cases the water would have to be raised to the top of the hill; the cost of pumping from the low-level well

would be considerably less and its maintenance less troublesome. Making due allowance for the increased cost of pipe lines from a well situated some distance away on the low ground, Mr. Bradshaw still had no hesitation in recommending that the best solution of this water-supply problem would be the sinking of one or more wells on the low ground north or east of the Prome Hill civil station where the supply is assured, and the pumping of the water through a pipe line to the top of the civil station.

Na-hsy water-supply, Northern Shan States, Burma.

In his survey of the Northern Shan States, Mr. Leicester was requested to include the investigation of the water-supply at Na-hsy, a nodal point at the junction of the Burma Mines Railway and the main Namtu-Lashio road. It is a centre of the forest operations of the Burma Corporation, Limited, and is likely to expand in size. The present water-supply is defective, with the result that the area has been subject to cholera outbreaks. Mr. Leicester found the water-supply of this area a very difficult question. A well-site was chosen at the foot of the ridge on the left bank of the 'logging' stream about 250 yards from the railway line at a point 1,000 yards from the station. The beds are here dipping steeply at about 60°, and, in order to increase the catchment area, it was suggested that, when the well had reached a moderate depth, a cross-cut should be made into the hill across the dip. This was done, but the shaft of the well unfortunately encountered a thick impervious band of rock and only a few layers of porous sandstone. A small amount of water—some 600 gallons daily—percolated into the well from the upper portion and through fault and joint planes. The well was 27 feet deep and the cross-cut had reached a distance of about 30 feet into the hill-side at the time of Mr. Leicester's second visit without striking any considerable quantities of water. Examination of the section disclosed in the well and cross-cut showed that the latter would have to be continued for a distance of over 200 feet before it was likely to strike water in any quantity. In view of the expense of continuing the cross-cut or of deepening the well, alternative proposals are now being considered. These consist of (1) piping water from a known spring some distance from Na-hsy; (2) sinking another well, 50 feet deep, 200 feet south-east of the existing well and cross-cutting to a distance of 100 feet; (3) sinking another shallow well elsewhere, and (4) sinking a well of 100—150 feet depth at a site

about 700 feet W. N. W. of the Public Works Department road. Comparing these alternatives, Mr. Leicester remarks that in (1) the supply is certain, but the cost of piping great. In (2) there is a probability, but no absolute certainty, of strikinga a sufficient quantity of water; the same might be said regarding the continuation of the present cross-cut to a total distance of 200—300 feet. (3) is considered useless. With regard to (4), a deep boring in the synclinal trough of the Na-hsy area should strike water if the upper sandstones occur above the calcareous shales in this area. The latter fact could be ascertained first by sinking a test pit or boring; even were this test favourable, there would be no certainty—though a probability—of striking water further down, and no guarantee that the water, if found, would be potable. On the whole, the most reliable solution of this difficult problem would seem to be a piping scheme from known springs.

Waziristan and Baluchistan.

The Government of the North-West Frontier Province having asked for the services of an officer to advise them in regard to the geological aspects of a number of dam and reservoir sites in Waziristan and Baluchistan, Mr. D. N. Wadia was deputed for this work. There are eleven proposed sites, which comprise two on the Kurram river, three on the Tank Zam, three on the Gumal system, one on a tributary of the Nari, and two on the Zhob river. Though scattered over a large area, they possess broadly similar features and a few general considerations seem applicable to all. Some of the proposed sites, Mr. Wadia believes, are old lake-basins, with portions of their silted-up bottoms yet preserved and there are valley depressions from one to three miles wide fronted by gravel-terraces, some hundreds of feet above the river beds, which are at present occupied by insignificant streams. These wide valley tracts alternate with deep narrow gorges with vertical precipices. The chief weathering agent is extreme range in daily and seasonal temperature causing alternate expansion and contraction in the rocks. The continued desiccation of this region has resulted in the establishment of almost desert conditions. The surface-water action is too feeble to transport to the Indus the continually growing mass of surface debris, which thus goes on accumulating *in situ*. Except the Kurram, none of the numerous transverse water-courses draining the Sulaiman range succeeds in reaching the Indus; these water-courses lose themselves in their own silt in the gently sloping Daman plains of Derajat.

The geological structure of the ground at the majority of the dam-sites is of great simplicity, and but for the difficulties interposed by the physical and climatic conditions of the region, the damming of the spasmodic river-courses, which at present waste the greater part of their annual discharge in uncontrolled torrential floods, would be an easy process. The main drainage of Waziristan, descending the Sulaiman range and the Daman tract to the Indus, cuts transversely across broad, parallel, N.N.E.-S.S.W. belts of folded Siwalik, Eocene, Cretaceous, and Jurassic rocks of various degrees of hardness, thus producing at several localities ideal conditions for the creation of artificial reservoir-basins in the wider parts of the valleys by barricading the downstream gorges. This process has, indeed, repeatedly operated in the past; witness the two or three extinct lake-basins in the Gumal and the Zhob, of which the Gul Kach basin, over 30 square miles in area, with its conspicuous lines of high-level beaches, is a well preserved instance.

While, however, the impounding of reservoirs by this method seems easily practicable, the peculiar geo-dynamical and hydrographical conditions arising from the desert climate of this region raise several difficulties, which, however, in Mr. Wadia's opinion, are not insuperable by modern engineering practice. The chief of these difficulties are as follows:—

(1) The great thickness of loose spongy surface deposits of gravel which mantle all the valleys would cause much loss of water by underground seepage from the sides and bottoms of impounded reservoirs. A considerable part of this would be permanent loss, not recoverable in the lower parts of the valleys. Fine silt would ultimately seal them up, but effective puddling might require several years.

(2) Loss by evaporation in a hot and dry climate, with a summer of over six months' duration, is a serious factor

(3) The violence and size of the N. E. and S. W. monsoon floods, for which these rivers are notorious, would cause severe periodic strains on the structure of solid dams.

(4) The great silt-bearing capacity of these floods is well-known and with proposed reservoirs of moderate capacity (which alone are practicable under present conditions) the possibility of their filling up, or being seriously

reduced in volume in a few years has to be considered, unless means are devised to discharge with the sluice waters the debris deposited annually in the basin. Some observations, which Mr. Wadia was able to make on the thickness and extent of sedimentation on a flood-swept tract, where the velocity of the flood-waters received a temporary check, seem to show that the capacity of an impounded basin might be reduced by as much as 40-45 per cent. in some parts, in 10 years, by unretarded sedimentation.

(5) The cohesion of the rock-body is undermined to some depth by the effects of isolation. High and heavy masonry dams, therefore, of uniform composition, seem inadvisable in the majority of cases, for the rocks have insufficient durability and cohesive strength to support them.

Some of these adverse conditions could be met by selecting that type of dam known as the 'loose-rock fill,' advised by the Chief Engineer, North-West Frontier Province. At the Gul Kach, Badanzai, and Brunj sites the construction of this kind of dam could be carried on in flowing water, while at Khajuri, Ahnai, and Shahur, a small length of diversion tunnel, for which the geological structure of the ground is suitable, could be constructed without undue expense.

The Gul Kach Reservoir Site. - The Gul Kach site is unique in being a natural basin in the upper Gumal, an old lake hollow, filled with the typical deposits of an extinct lake, with a rocky gorge at the eastern end of it serving as its only outlet. The area, part of which lies in Afghan territory, is considerably over 30 square miles and is covered with extremely fine silt, the central parts of which are being cut by the present channel of the Gumal into isolated mounds. The exit-gorge is 200 feet wide, with precipitous sides nearly 500 feet high. The rocks are grey, imperfectly cleaved slates with lenticular intercalations of limestone and quartzitic sandstone. The strike of the slates is directly across the gorge with a prevalent downstream dip, E. 10°S., varying from 25° to 40° in amount. The strata show a good deal of puckering and contortion with a much-fractured rock-surface which weathers badly, giving rise to unstable slopes covered with the remains of periodic landslips. With depth the rock improves in strength and solidity.

A solid masonry dam inside the gorge with flanking rocks of the above description is out of the question and Mr. Wadia was unable to approve of the proposed site which lies 1½ miles within the gorge. Besides the risk involved from unstable valley-slopes, which are here precipices 500 feet high, another disadvantage of a dam situated so far downstream would be the loss of imprisoned water through the fissured sides of the gorge; this infiltering water would further weaken the base of the precipices.

A much more favourable, though less ambitious, site is, in Mr. Wadia's opinion, near the entrance of the gorge. The flanks are here more resistant and the bed-rock for the dam-foundation is exposed for nearly three-quarters of the width of the river-bed. A dam 150 yards in length and 80 feet in height at this point would store back more water than one of 115 feet in height at the downstream site. One or two bluffs of rock standing in the middle of the valley might be either made to serve as part of the apron, or taken in as integral parts of the body of the dam-structure. A spill-way exists across a natural saddle. The only disadvantage of this site is that the cliffs are not high enough to allow the dam being raised beyond 80 or 90 feet, especially with a reservoir-basin whose capacity increases by thousands of acre-feet with every foot of increase in the *bund* height.

The existing deposits of fine silt at Gul Kach attest the water-tightness of this basin. The extreme slowness with which such fine matter has been laid down points to the retention for long periods of large volumes of standing water.

Building stone of the required quality is not available at the spot, but would have to be quarried from the limestone and quartzitic strata of the hills N. and N.N.E. of Gul Kach.

The Khajurikach Dam Site.—About three miles below the junction of the Gumal with the Zhob, the united stream has cut a deep gorge, the Adam Kak gorge, through a limestone ridge. The direction of the gorge is diametrically across the strike of the limestones, the dip being uniformly upstream, 45°-55°, W. 5°-10° S. The Adam Kak defile is ½ mile long and is only 60 or 80 feet wide at places, with its south flank rising sheer 1,300 feet from the bottom of the valley. Except in earthquakes of unusual intensity the stability of this cliff, resting on solid rock, and with the stratification-planes transverse to the valley-side, is not likely to be threatened. The rocks are dark-grey flaggy limestones, of probably Lower Eocene

age, generally without shale partings and immune from severe crumpling or folding. No wide, gaping joints or fissures are present, though minor folding and some local strike-faults of small throw are seen. The debris of a landslip of considerable dimensions lies at the entrance of the gorge on the right bank, but good clean bed-rock is exposed at the river-bed almost throughout the gorge.

Mr. Wadia considers a site some hundred yards below the entrance as the most suitable, being well on the upstream side of the largest of the minor faults seen. A dam up to 150 feet in height would be possible here with fairly sound rock for foundation and sides. The few open bedding-planes would have to be grouted, as well as any wide joints revealed on clearing the sides. The debris of the old landslip referred to above forms a sort of natural apron to the high hill-slope above it and as it lies at a safe natural angle of repose, it should not be disturbed in order to obtain building-stones. Enough material of excellent quality, fit for the rock-fill, occurs elsewhere near the site. A diversion tunnel through one of the flanks would be necessary. The geological structure at the suggested site seems favourable for the safety of its roof and sides.

The Khirgi-Kaur Reservoir Site.—The Khirgi-Kaur Reservoir project has as its object the closing of the drainage outlet of a natural topographic depression between Manzai and the Girni militia post, by an impounding dam, or *bund*, near Kaur and the filling of it, partly with the water from the Tank Zam diverted into it by means of a tunnel near Khirgi, and partly from the Gumal through an old deserted channel.

The Khirgi basin has originated in a manner peculiar to Waziristan through the coalescence and re-distribution of a number of talus fans belonging to the freshets and torrents descending from the surrounding higher ground into the Narsas bed. The catchment area of the trough is insignificant, its bed being dry for 10 months of the year, but owing to the pan-shaped configuration of its bottom, the storage capacity would be remarkably high, and Mr. Wadia considers it would therefore be possible to utilise the surplus flood-waters of the two neighbouring streams.

The bottom and sides of the Kaur trough are constituted of coarse gravelly alluvium with subordinate seams of sand. Its eastern or Manzai flank is steep and cliff-like, dissected by scores of ravines which, even during the Rains, discharge hardly any water into the Narsas. The opposite flank is a natural *glacis* slope of

unassorted scree. There are no large pores or vacuities in the gravel and the whole has a degree of compactness which allows it to stand in vertical scarp-faces of 50-80 feet, but although its porosity is diminished, it is far from being water-tight. The level of ground-water, even in the Narsas bed, is deep, the whole discharge being carried underground.

The conversion of such a tract into a storage reservoir can only be recommended on the chances of its ultimately becoming water-tight by the puddling effect of the silt brought by the feeders. That, for several years, a considerable loss of water would accrue, through a bed that has no solid or impervious substratum to check the under-flow, is a foregone conclusion. In Mr. Wadia's opinion the success of the project would depend upon the quality and quantity of the silt brought in and laid down, in the right position, in the area to be enclosed.

The *bund*, which would be from two to three miles long, could be constructed of the Manzai terrace gravels by the hydraulic fill process; it would need to be adequately protected from the action of the numerous shifting torrents descending the Girni Sar *glacis*.

The Shahur Tangi Dam Site.—The Shahur Tangi is a cañon-like defile, only 11 yards wide at one point, excavated by the Shahur tributary of the Tank Zam, out of soft, rather poorly consolidated sandstone of doubtful Cretaceous age. The sides of the gorge are vertical faces of this sandstone, 175 feet high on the north and 220 feet on the south side; the strike of the massive strata is transverse to the gorge, with a downstream dip of from 80° to 90°. The individual sandstone beds are from 1 to 8 feet thick, without notable shale intercalations and are, at the proposed site for the dam, free from the rather high degree of disturbance seen elsewhere in this rock series. There are no open joints, fissures, or other divisional planes, besides the somewhat wide-spaced bedding-planes. The bed-rock is not exposed at the stream-bottom; its depth, however, is not likely to exceed 20 feet or so and when seen will most probably be a clean, water-worn surface.

The structural features of the Shahur dam-site are reported by Mr. Wadia to be excellent and the foundation and flank rock, though weak in detached pieces, is sufficiently firm in mass to take the weight of a rock-fill dam and withstand the resultant thrusts. A dam of 100-130 feet height may be safely recommended, though

the low tensile and crushing strength of the Shahur sandstone would be against a heavy or high masonry structure. The wide bedding-planes will have to be well grouted and made water-tight and the unconsolidated and partly-cemented patches of rock scraped out from the foundation and sides. The building-stone will have to be brought from some distance, as much of the material obtained from the spill-way excavations, or from local quarrying, is likely to lack sufficient rigidity or cohesion.

The Ahnai Tangi Dam Site.—The rocks at the Ahnai gorge consist of red, purple, and grey shales with interbedded sandstone and limestone of varying colours. These are folded into a disturbed sinuous anticline, with its axis, in the main, N.N.E.-S.S.W., traversing the Ahnai valley obliquely. At the site of the proposed dam there occurs a thick band of flaggy, grey limestone (270 feet) with a steep upstream dip and strike transverse to the gorge. There are some narrow fissures in the rock, beside the usual set of joints and in a minor degree flexuring of the beds. The limestone is extremely fine grained and homogeneous, slightly argillaceous and almost lithographic in texture. The folding present in the rock is not of a character to affect the strength of the foundation or sides of the proposed dam. There are one or two minor slips and faults, especially in the left bank, which will need attention.

The limestone precipice on the right bank of the gorge is a little out of the perpendicular, the upper portion of the overhanging cliff, supporting the Ahnai militia post being a clean master joint face. This vertical scarp in a rock of such high crushing and shearing strength as the present limestone will not, except in earthquakes of high intensity, endanger its stability, especially as the lower part of the precipice will be supported by the wide flank of a rock-fill dam. This scarp appears to be an old feature and no recent landslips were noticed around the spot. The thickness of the superficial stream gravels concealing the bed-rock is not likely to exceed the ordinary depth of foundation of a rock-fill dam.

The longitudinal profile of the Ahnai Tangi, with its most constricted part in the middle, shews ideal structural conditions permitting of wide front and back aprons which will 'key' the whole structure securely. There will be no difficulty in obtaining suitable building stone, as the excavation for the spill-way will contribute the greater part of the required amount. The local limestone can yield hydraulic lime on burning because of its argillaceous content.

The Hinis Tangi Dam Site.—The Hinis gorge is cut across a high cliff of Upper Siwalik conglomerate. The strata strike N.N.E.-S.S.W. and have a dip of 30°-45° upstream. The narrowest part of the defile is 110 yards across, flanked by wall like conglomerate cliffs, 200-250 feet high. The rock varies from a gravelly to coarse bouldery conglomerate with pebbles of 1-5 inches in diameter, crowded in a scanty matrix. There are numerous pockets of loose sand and grit. Periodic landslips and a wide belt of scree material at the foot of the cliffs are forcible reminders of the instability of the valley sides

The geological structure of the Hinis Tangi dam-site is, according to Mr. Wadia, unfavourable. Besides the weak flanking rock the foundation would quite likely have to be deep and might be little better than a loosely aggregated mass of boulders. Material suitable for the rock-fill would have to be carried from some distance, unless it were proposed to make use of the more angular boulders from the local scree debris. Heavy loss of water, through underground and side percolation would have to be taken into account, because of the high porosity of the gravels.

The Kurram Tangi Weir Site.—The proposed Kurram Tangi weir-site is at a narrow part (450 feet) of the Kurram bed, north of Bannu, as it leaves the Siwalik hills and enters the wide Bannu plain. Upper Siwalik rocks crop out here in low mounds, the outcrop on the right bank being 400 feet wide, that on the left only 150 feet. From below upwards, it consists of moderately consolidated sandstone, loose sand-rock, and a bed of pseudo-conglomerate, capped by a fairly compact sandstone. There is a great deal of lateral variation in the strata, a feature for which the Siwalik series is notorious. The dip varies quickly from 45° on the left to 20° on the right bank, this fact doubtless accounting for the great discrepancy in the width of the outcrop on the two opposing slopes.

A strike-fault of considerable throw occurs about 200 yards above the weir-site and brings up Lower Siwalik brick-red clays, striking N.-S., in juxta-position with Upper Siwalik beds striking in an almost E.-W. direction. The plane of contact of this fault, however, appears to be well-cemented by the fine red Chinji clays which form one of its walls.

The composition of the local rocks and this faulted junction would not admit of a dam structure being raised at this site, but a weir, founded on the better consolidated beds, especially on the pseudo-

conglomerate band, which has an upstream inclination, would be free from risks. Mr. Wadia found it impossible to estimate exactly the depth of solid rock below the superficial alluvium; it may be 30 feet or less. The upstream toe of the weir should be well below the fault-line.

The Dareh Tang Dam Site, Kurram Valley.—The topography of the Dareh Tang area provides a reservoir basin of remarkably high storage capacity, commanding a wide irrigable area, but a very poor site for a dam. The shallow circular depression, through which the Kurram meanders on a sandy bed from one to two miles wide, carrying a thin sluggish stream, is a real structural basin—a synclinal trough with in-dipping rocks on nearly all sides, filled with sub-aerial and fluviatile deposits of Pleistocene age. Dareh Tang is the only gap in the Shinghar-Marwat range of hills through which the Kurram escapes into the Indus basin.

The rocks at the site consist only of sub-aerial drift sand of Pleistocene or later age, forming much-indented cliffs and mounds about 100 feet high. The loosely compacted sand beds are tilted at angles of 15° to the west. There is no 'solid rock' *in situ* beneath the drift. The depth of sand in the bed of the river must be considerable and in Mr. Wadia's opinion beyond the ordinary depth of foundation of a dam.

The most noteworthy feature of the present site is the capacious basin which can be enclosed even by a low dam; a 50-foot barrier would, for instance, impound a reservoir of 155,000 foot-acre capacity. The bed being, however, entirely composed of sand to an unknown depth, Mr. Wadia feared (1) that this pervious bottom would not allow any water to be held, (2) that the water so lost by percolation would drain underground and gravitate down to the Indus and (3) that the ordinary amount of silt brought down by the Kurram might not be able to puddle it effectively for many years. These fears were, however, considerably relieved by the observation of the behaviour of ground water at Thanedarwala station, 3 miles west of the Dareh Tangi exit, in a well-boring, the only deep bore that exists in this area. This well is 155 feet deep (30 feet of dug well *plus* 125 feet of tube at the bottom) and the spring level of the well is a few inches above the ground level. It is thus an artesian well and its existence suggests that the underground water is held under considerable head at 155 feet depth and that its downward and eastward drainage is checked by some

obstruction. This single observation, so far as it goes, tends to suggest that the Kurram basin is a more or less closed artesian basin, the imprisoned water within which is withheld from further progress to the Indus by the inward-dipping rocks of the Shinghar-Marwat range at its only outlet. This circumstance indicates, in Mr. Wadia's opinion, that if a reservoir can be impounded at Dareh Tang the chances are that it will not lose its water by rapid underground drainage, but will tend to raise the permanent level of saturation of the whole area and to improve materially the prospects for artesian well-borings therein.

No description of a masonry or rock-fill dam, however, is possible at this site with foundation and flanks composed of blown sand. A compact earth *bund* of great width and weight, with a floating foundation, protected by modern engineering devices, is the only possibility, according to Mr. Wadia. The banks of the Dareh Tang reservoir would need to be strongly protected by vegetation, stone-facing, etc., to resist wave action during storms, the effects of which against such loose rock might be severe.

As an alternative measure for obtaining a water supply, Mr. Wadia is of the opinion that the installation of pumps in filter-cribs at the proposed site is worth serious consideration. Pumping at moderate or shallow depths would yield good supplies of water, even in the hottest months of the year when the river is dry.

The Badinzai Dam Site, Zhob River.—An alluvial flat in the upper Zhob valley, 9 miles south of Fort Sandeman, is succeeded by a narrow defile downstream, and a dam is proposed in this section of the river in order to impound an irregularly shaped reservoir basin, estimated to contain 28,000 acre-feet of water, with a 75-foot dam.

The rocks in the gorge are loose, friable, grey and drab clays, carrying interbedded thin, flaggy limestones and black-coated sandstones, all of which are extensively fissured. The black, serrated picturesquely-worn crest of the Badinzai hill is due to a massive intrusion of serpentinised peridotite. Structurally the valley lies along the crest of a sinuous anticline, striking N.N.E.-S.S.W., a structure best suited to the escape of any stored water by seepage from both the sides. No favourable site under such circumstances, could be found within the defile. The only site, which in Mr. Wadia's opinion is free from grave risks, is the one close to the neck of the gorge, where, though the structural features of the rock-exposure

as well as its composition are the same, they would not have the same adverse effects on a dam structure situated at the upstream extremity.

The present scheme comprises the creation of a retarding or delay basin and not an irrigation storage-reservoir; hence a certain amount of leakage, which is sure to take place through the porous beds on the flanks, is not of serious consequence. If, later on, a storage reservoir be decided on, the water-tightness of the site will have been sufficiently tested for alternative or remedial measures to be adopted.

The Brunj Dam Site, Zhob River.—Three sites about 11 miles N.N.E. of Fort Sandeman for the Brunj dam were examined :—

(1) W.-by-S. of Brunj rest house,

(2) 1 mile further upstream,

(3) Near milestone '10,' 2 miles above Brunj.

The structure, as well as the composition of the rocks shattered shales and clays—at the first two sites is unfavourable. The dip of the beds is either downstream or the strata are buckled into a sharp anticline with its axis parallel to the valley; a dam, consequently, would have to be laid across a large number of bedding-planes of shaly, fissured rocks.

At site (3) the Zhob bed, 250 yards wide, traverses obliquely a squeezed syncline with N.N.E.-S S.W. strike. The rocks are fractured sandy shales with brown, sandy limestone partings. On the left bank, only one limb of the syncline, with upstream dip, is left uneroded, while the solitary elevation on the right bank consists of the reverse limb of the fold. This locality might so Mr. Wadia remarks—with adequate treatment of the flanks, provide a tolerably safe site for a rock-fill dam of 50 or 60 feet height and 300 yards length. Natural saddles exist for a spill-way. At Brunj as well as at Badinzai there occur in the valley bed fairly large patches of extremely fine marly clay of great plasticity—probably the remains of the old lake-bottom.

Vitakiri Reservoir and Dam Site, Loralai District.—A torrent of small perennial discharge, having eroded a defile through the middle of an amphitheatre-shaped ridge of Nummulitic limestone underlying a wide band of clay, has created a site which, in Mr. Wadia's opinion, is very favourable for the impounding of a small reservoir of some 10,000 acre-feet capacity, by means of an earthen embankment.

The Nummulitic limestone forms a series of parallel strike-ridges, with an E.-W. strike and northerly dips, separated by low-lying flats composed of fine clayey shales. The basin of the proposed reservoir is one such expanse of shaly ground, floored by thick impervious clay, ensuring a perfectly water-tight bottom. The south wall of the reservoir is formed by the outcrop of the underlying limestone, which rises 40-50 feet above the surface with a steep dip-slope. The dam-site is a rather wide gap in this ridge, which it is proposed to fill in by an earth-and-gravel embankment, 4,000 feet long, and of 24 feet average height. The outlet sluice-way will be a tunnel through the limestone, 1,000 feet long. The thick, massive beds of limestone, with strike transverse to the tunnel, will withstand the pressure and action of water well, and will need no lining beyond the sealing up of the bedding-planes and joints; the clay section of the tunnel, however, will have to be lined throughout.

Excellent building material for the construction of the embankment exists at the site.

Water-supply, Rawalpindi, N.-W. Railway.

At the request of the Agent of the North-Western Railway, Dr. Cotter was asked to investigate the question of improving the water-supply for locomotive boilers at Rawalpindi. A trial boring had already been sunk in one of the railway yards on the west ridge north of the race-course. The depth reached was 930 feet, but no abundant water was forthcoming. Samples of strata passed through were forwarded to the Geological Survey office, and showed the following section:—

From top to 160 feet .	Calcareous and arenaceous clay (evidently Loess).
160 ft. to 165 ft. . .	Calcareous clay with nodules and with pebbles of limestone.
165 ft. to 240 ft. . .	Calcareous and arenaceous clay.
240 ft. to 280 ft. . .	Limestone gravel and pebbles.
280 ft. to 290 ft. . .	Conglomeratic calcareous clay with boulders of arenaceous limestone.
290 ft. to 305 ft. . .	Purplish clay with a little limestone gravel.
305 ft. to 345 ft. . .	Pebbles of hard greyish limestone with foraminifera.
345 ft. to 370 ft. . .	Greenish calcareous conglomeratic clay with pebbles and gravel of limestone.
370 ft. to 390 ft. . .	Arenaceous and calcareous clay.
390 ft. to 420 ft. . .	Pebbles of calcareous and ferruginous sandstone with calcareous arenaceous clay.
420 ft. to 455 ft. . .	Calcareous clay with limestone gravel.
455 ft. to 470 ft. . .	Pebbles of greyish slaty limestone with foetid smell.
470 ft. to 475 ft. . .	Calcareous ferruginous clay with limestone gravel.

475 ft. to 480 ft. . .	Arenaceous and calcareous clay with limestone gravel.
480 ft. to 930 ft. . .	Calcareous and slightly arenaceous ferruginous clay with limestone gravel.

Rawalpindi is situated on an alluvial basin surrounded by Tertiary rocks, of which the Murree series is exposed in the immediate neighbourhood of the town on the south and west. The more superficial portion of the alluvium is an unstratified loess, but lower down it carries gravel and boulder beds. The loess acts as an impervious cap to the water which accumulates in the gravel beds. These conditions are exactly similar to those prevailing at Quetta, where artesian wells draw water from gravels underlying the loess. Artesian water is found at about 100 feet below the surface of Khana Dak near Rawalpindi. Here the country is low-lying, but the artesian pressure is so small that the water, according to Dr. Cotter's investigations, refuses to rise more than 6 feet above the ground level. Rawalpindi and the west ridge are roughly 60 feet higher than Khana Dak, so that an artesian flow is not to be expected; the chances are, therefore, that the water from the basal alluvial gravels will rise up the pipe of any well to within 60 feet or so of the surface.

The alluvial deposits rest upon an uneven and denuded surface of Tertiary rocks. In the case of the alluvium of the railway yard we should expect these rocks to belong to the Murree series. The base of the alluvium is usually marked by a boulder bed, and the above well section shows a boulder bed, between the levels 280 to 290 feet, overlying purplish clays. Purplish clays are very characteristic of the Murree series, but are not found in the alluvium. We may conclude, therefore, that the depth of the alluvium here is 290 feet. Water derived from the Murree series is apt to contain considerable quantities of chloride, sulphate, and carbonate of sodium and other salts. It is, in fact, very unlikely that water of sufficient purity for locomotive boilers would be found in the Murree series, and Dr. Cotter thinks it inadvisable to waste money in searching for pure water in these rocks. Dr. Cotter, therefore, has advised that the above boring should be plugged up to the base of the alluvium and that samples of water should be taken from the plugged well and compared with the water from the Lei river which is now being used by the Railway. These samples were examined by Dr. Christie, Chemist to the Department, who reports as follows :—

The Lei water is apparently derived from a well, and not directly from the river. Of the waters collected in the vicinity of Rawalpindi

that from the Lei well is the best. The water from the Khana Dak tube well, which is some miles away, is very slightly better. The water from the trial boring near the engine-shed is like that from the electric supply station and far worse than that from the Lei well. The water from the brewery well has a considerably greater temporary hardness; its permanent hardness would probably be about the same.

Dr. Christie expressed the opinion that the Railway should continue to use the Lei well water of which there is a plentiful supply. For boiler purposes this water, considered on its merits, would be classed as poor. It is, however, not past redemption by a softening plant, and it is, at any rate, an improvement upon the water from the railway yard well. Whether the cost of working and maintaining a softening plant would be covered by the decrease in boiler-cleaning and repairs, in fuel, in the increased number of locomotives in service, and in their less rapid depreciation is a question for the railway authorities to decide. Dr. Christie tested the Lei well water with a Stabler's softening plant with successful results on a small scale. The total dissolved matter was reduced from 370 parts per million to 149. The carbonate figure dropped from 188 parts per million to 50. The most important figures are those for calcium and magnesium; these were reduced from 86 to 6 parts per million and from 21 to 7 parts per million, respectively.

Hasan Abdal Springs, Attock district, Punjab.

The Hasan Abdal springs in the Attock district of the Punjab were examined by Dr. Cotter. There is one large spring north-east of Lala Rukh's tomb and a number of springs between the tomb and the Sikh temple and also in the Hasan Abdal stream below. The temperature of the springs near Lala Rukh's tomb was found to be 58°F., that is to say, slightly warmer than surface water at the time of year. As an experiment, one of the springs had been enclosed and the water directed into a masonry cistern. Within the latter the water level rose to no more than 3 inches or so above the level at which the spring emerged. From this it was evident that the hydrostatic pressure is very low.

The rocks at Lala Rukh's tomb, with which the springs are associated, are Triassic limestones dipping in a north-easterly direction at an angle which at the springs is about 30° and steepens to about 60° further up hill. Dr. Cotter is of opinion that the quarry which it is proposed to construct in the neighbourhood will cause

no damage to the springs. The proposal is to excavate the hill-side and level off a space the floor of which will be on a level with the road. The floor of the quarry would then be about 6 feet above the level of the springs and should be dry. Dr. Cotter remarks that were the springs under greater hydrostatic pressure, the water would probably rise up internally into the hill, but he considers that it comes through water-channels in the limestone from some distant source such as the Margala hills. TheHasan Abdal hill itself cannot constitute the chief catchment area, since it is far too small a hill to feed so large and perennial a stream as that of the Hasan Abdal. It is well known that water will travel great distances underground through limestone.

Dr. Cotter points out the risk of choking springs by constructing masonry dams or reservoirs around them. Such reservoirs retard outflow and flood back the springs, the result being that the increased hydrostatic pressure drives the water to seek some other outlet, while the sluggish outflow encourages choking by permitting the deposition of sand in the channel. If the springs be allowed to flow rapidly, as nature intended they should, they will keep their channels scoured out and free from deposit. Unless the level of water in the reservoir is below the level at which the spring issues, the construction of such masonry dams near the exit of the spring is a mistake.

Hazara district, Punjab.

In June, Dr. Cotter visited the site of a proposed well in the Civil Hospital compound at Baffa in the Hazara district, Punjab. The site was composed of thin gravels with solid granite beneath. It was considered unlikely that the granite would be sufficiently permeable to yield water at this site. It was recommended, therefore, that a supply of water should be taken from a neighbouring spring in the hills to the north of the hospital, and that the supply should be led to the hospital by a pipe.

Eastern Salt Range, Punjab.

During the normal course of field-work in the eastern part of the Salt Range, Punjab, Mr. E. R. Gee, made observations on the water-supply of that area for the benefit of the Punjab Government. The area examined largely comprises the Pind-Dadan-Khan *tahsil* portion of Sheets 43 H/1, H/2, and H/6. Mr. Gee notes that this

area might, in the matter of its water-supply, be divided into four separate tracts both topographically and geologically:

1. The main scarp slopes forming the southern face of the range.
2. The plateau to the north, including the villages of Ara, Umrila, Basharat, and Lahr.
3. The alluvial plains between the foot of the scarp and the Jhelum river.
4. The alluvium-covered area, and adjoining Siwalik country, of Waghh and Dhok Chanda, west of Chambal ridge (Sheet 43 H/6).

The larger streams which drain the southern slopes of the range are usually fed from fresh-water springs arising out of the hillside either from the basal beds of the Magnesian Sandstone group, or from the bottom of the Nummulitic limestones. Outcrops of Salt marl in the lower courses of these streams in the Chanuwala-Jutana tract, cause contamination of the water as the plains are approached. Further east, where the Salt marl is absent from the lower slopes, saline springs arising out of the purple clay-shales in the lower part of the Purple Sandstone group, sometimes render the water unfit for human consumption. It is therefore necessary to tap the streams above the outcrops of these saline beds. This has been done in the case of the Bhadrehu Kas for the supply of water to Chanuwala railway station, and also in the case of the western stream of the Baghanwala gorge, for the supply of Baghanwala village.

Mr. Gee observes that the question of supplies of fresh-water for certain tracts of the plateau is very acute. During the dry weather a number of the springs and wells which exist, almost dry up, so that the needs of several adjoining villages have to be satisfied, usually quite inadequately, from a single spring or well which happens to have struck a more constant flow. In the south-eastern portion of the plateau, in the vicinity of Ara, conditions are more fortunate. Several good springs supply the needs of the population, and wells sunk in the alluvium and Tertiary sandstones of the Are-Dhok Lohar area, supply water for irrigation purposes from a comparatively shallow depth. Further north and west, however, the situation is very different. The Nummulitic limestones, covered in places with patches of alluvium, are thicker than to the south-east and, since the main water-bearing horizon is near the

base of these limestones, it is necessary that the wells should be sunk to a much greater depth. In several instances wells were made in these Nummulitics to a depth of from 80 to 100 feet. In certain of these an inconstant supply of water has been obtained, while others are dry for the greater part of the year. The alluvium of the Basharat area, to the east of Mt. Chel, is often very thick along certain narrow tracts, which are suggested by Mr. Gee to represent old worn channels in the limestones, now filled with alluvium. Wells sunk into these limited, deep, alluvial tracts give quite a good supply. Several disappointing attempts to obtain water within the Nummulitics of this portion of the plateau, at depths usually up to 80 feet, have disheartened the local population. Were definite water-bearing horizons first proved by boring, Mr. Gee has reason to consider that the villagers would be willing to deepen their wells accordingly; as an alternative their needs might be supplied by a number of tube-wells. Mr. Gee observes that the main water-bearing zone is near the base of the Nummulitic limestones, probably at a depth varying from 120 to 150 feet in the Umrila-Haral area, though increasing to at least 200 feet to the south-west.

The water included in the alluvium at the foot of the scarp in those areas where the streams are contaminated by the Salt marl, and by saline springs from the purple clay-shales above, is naturally slightly saline, and unfit for human consumption. The water-level is usually about 20-25 feet from the surface. As we go southwards towards the Jhelum river, plentiful supplies of good water are obtainable in the shallow wells sunk into the alluvium.

In the Dhok Chanda-Waghh area to the west of the Chambal ridge, boulder-alluvium covers the tract at the immediate foot of the scarp, and passes westwards into sandy alluvium in the vicinity of Naghial and Waghh. Further west the Siwaliks crop out dipping steeply to the N. N. E. Wells sunk in the sandy alluvium around Naghial and to the north as far as the Bunhar river, obtain a plentiful supply of water at a depth of about 30 feet in the south and of 15-20 feet as the Bunhar is approached. To the southeast of Naghial the water-level is naturally at a greater depth, and within the boulder-zone near the foot of the scarp no constant supply can be expected. The supply for Dhok Chanda and Dhok Khair villages is obtained from large artificial tanks. Mr. Gee suggests that by constructing a small dam across the *nala* just south of Dhok Chanda, at the outcrop of the Purple sandstone,

a much larger supply could be reserved. Just south of Dhok Khair village a deep well had been sunk in the Middle Siwalik strata, but the results were disappointing. Considering the geological structure of this tract, the absence of water in this well was not surprising. Mr. Gee has suggested that a well should be sunk in the lower ground of the alluvial tract to the northeast of the village.

Jhansi, United Provinces.

At the beginning of the camp-season, Dr. A. M. Heron inspected the proposed site for an earthen dam on the Ghurari Nadi near Babina, about 15 miles south of Jhansi. This scheme is to be carried out by the agency of the Great Indian Peninsula Railway, and is to supply water to the civil and military station of Jhansi, and to the railway workshops. The proposed dam will be a little under a mile in length and about 70 feet high above the present stream-bed, and will impound a sheet of water over 2 miles in maximum length and breadth, in a wide shallow valley lying within the Orchha State.

A line of bore-holes, 25 in number, and spaced on the average about 250 feet apart, had been put down to a maximum depth of 50 feet, and showed that the alluvium consists of coarse angular sand with a varying admixture of yellow clay, and that the bed-rock is everywhere Bundelkhand gneiss. The latter is really a homogeneous, unfoliated granite, varying only in grain. The vertical joints of the granite run approximately in N.E.-S.W. and N.W.-S.E. directions, and, with the horizontal joints, divide the rock into rough cubes of the order of a foot to a yard in side. Apart from joints, the bed-rock is sound, and little leakage through it need be expected, provided that ordinary precautions are taken in founding the clay core or the dam in a trench cut deep enough to be clear of decomposed rock and open fissures, and in cementing any cracks in it. In any case there is no geological alternative, for Bundelkhand gneiss of the same character surrounds Jhansi for many miles. The overlying alluvium is highly porous, and great care will have to be taken to ensure that the clay core of the dam is thoroughly impervious. The chief difficulty of the project will be that of obtaining at reasonable rates the large amount of clay necessary for the construction of the core of the dam, for the Bundelkhand gneiss produces a very sandy alluvium, and clay is scarce. Dr. Heron has indicated the presence, on the site, of surface patches of loamy clay, which may possibly be suitable, and are at least

worth trying in bulk under conditions similar to those to which the core will be subjected. The extent of these deposits is at present unknown.

ZINC.

Merwar ; Rajputana.

During his survey of Mewar, Dr. Heron examined the ancient zinc mines of Zawar or Jawar (24° 21′ ; 73° 45′). These are said to have been discovered in the reign of Rana Laksh Singh or Lakha (1382-97) and produced lead and silver, and, up to 1766, are stated to have yielded a net annual revenue exceeding two lakhs of rupees. They finally ceased working at the great famine of 1812-13. The ore consisted chiefly of zinc carbonate or smithsonite, with argentiferous galena.

Workings are numerous in the neighbourhood of Zawar, but the principal ones run for over a mile and a quarter near the crest of a high ridge above the hamlet of Balria, about 2 miles N.E. of Zawar ; they are in vertical gritty Aravalli limestone, one of the several lenticular limestones which occur locally in the phyllites. This excavation is a vast open-cast, varying in width and depth, with vertical sides. Its average breadth is about 80 feet, and average depth perhaps 40 feet, but irregular caverns go down an unknown distance below the bottom of the open-cast, and it is covered with great blocks which have fallen from the sides, or have been left in the process of working. No sign of identifiable zinc or lead ore was visible either in the workings or the dumps except a few tiny stringers of galena. Much iron is present as ferruginous quartz. On assay, representative specimens of this gave 2·970 per cent. of zinc and 0·041 per cent. of lead. If any definite veins of smithsonite or galena have been present, they have been entirely removed. It is believed that the limestone has been replaced by silica and iron ore, with subsequent brecciation, as is so common in the Aravalli limestones, and that the zinc and lead ores were deposited in the fissures of the breccia. The ore appears to have been treated in earthen pots, which were heated in groups on a fire, and the sublimate collected in long narrow necks projecting from the lids of the pots. The light clinker, which still fills many of the old pots, gave on assay 7·029 per cent. of zinc and 0·150 per cent. of lead, without any copper. Another process has produced a black glassy slag, containing 13·761 per cent. of zinc and 3·538 per cent. of lead, also without copper.

GEOLOGICAL SURVEYS.

Auranga Coal-field, Bihar and Orissa.

Dr. J. A. Dunn completed his survey of the Aurunga coal-field, to the eastern end of which his work was confined. In the west he had previously found it difficult to recognise the clear sub-divisions of the Lower Gondwanas above the Talchir series, but in the eastern area there was little difficulty in distinguishing the Barakar and Raniganj stages and in separating the latter from the overlying Panchets. Dr. Dunn found no coal-seams in the Raniganj stage, and has thus confirmed the view that these strata are increasingly coal-bearing eastwards, being at their best in the Raniganj coal-field. All the coal-seams in the Aurunga field are of Barakar age. Dr. Dunn has drawn attention to the irregular character of the gneissic floor on which the Gondwanas rest directly. In most places the Talchirs are missing, a condition evidently due to overlap of the Barakars on to the gneisses. In the vicinity of Rajbar the coal-bearing section of the Barakars is quite 200 feet above the base of the stage. North of Tubed, however, the coal-bearing beds of the Barakars were found resting directly on the gneisses, thus illustrating the irregularity of the gneissic floor and the overlapping of the younger beds on to older rocks. In the Tubed area the Raniganj stage evidently rests immediately on the coal-bearing beds of the Barakars. Dr. Dunn is of the opinion that though ironstone shales occur interbedded with the grits of the Barakars there is no evidence with which to establish an Ironstone Shale stage in the Aurunga coal-field. Dr. Dunn's opinions confirm those of forty years ago when this field was first surveyed by the Geological Survey. The coal is of poor quality and of no great economic importance.

Singhbhum District, Bihar and Orissa.

Dr. J. A. Dunn, assisted by Mr. A. K. Dey, Sub-assistant, commenced the survey of the Dhalbhum subdivision of Singhbhum, including the most important section of the 'Singhbhum Copper Belt'. The rocks met with belong to the Iron Ore series and are similar to and probably identical with the rocks previously mapped in western Singhbhum. A large part of the work was along a 'zone of overthrust' which is a continuation to the south-east of the zone of overthrust already described in north Singhbhum.[1] This zone

[1] J. A. Dunn, *Mem. Geol. Surv. Ind.*, Vol. LIV. (1929).

of overthrust, with which altered volcanic rocks of the Dalma type are associated, forms the copper belt in Dhalbhum. To the south-west of this belt there is an immense development of quartzites in the Iron Ore series. Phyllites, mica-schists, epidiorites, and chlorite-schists are also found. In north Singhbhum there is a progressive increase in metamorphism as the rocks are followed along the strike west from Chaibassa. In Dhalbhum there is found to be a similar increase in the degree of metamorphism of the rocks if they are followed to the east and south-east along the strike. According to Dr. Dunn south and central Singhbhum is an 'island' of relatively unmetamorphosed Iron Ore series rocks surrounded by their metamorphosed equivalents.

The Iron Ore series in Dhalbhum has been intruded by the Singhbhum granite. At the border of this granite there is a coarse-grained rock varying in composition from a basic gabbro through diorite to granodiorite. It is often veined by granite (sometimes a beautiful graphic granite), and is also intruded by later dolerites. In zones of shearing the basic rock appears as talc-schist and serpentine, and it is impossible to distinguish these from talc-schists derived from Dalma epidiorite. The basic rock insensibly passes into the granite, which, in this part of Singhbhum, is really a granite-gneiss. It seems to Dr. Dunn that there is every stage in differentiation from basic gabbro, through diorite (often orbicular) and granodiorite to adamellite and graphic granite. In his opinion, owing to later movement in the acid magma, the boundaries of the gabbroitic, dioritic, and granitic types are now distinguishable.

The Arkasani granite-gneiss of north Singhbhum continues here to the east and south-east as a series of impersistent tongues, some of them of large dimensions. At Mushabani ('Mosaboni') one of these granite tongues forms the country rock of the copper lodes, but is so completely sheared that it has lost its original granitic character and in places is best termed a felspathic schist.

The geo-anticline from northern Singhbhum is prolonged between the copper belt and the continuation of the Dalma range of volcanic rocks. In it occur mica-schists, granulites, and hornblende-schists. In places a well-defined bed of quartz-granulite often provides graphic evidence of the acute folding and thrust movements which built up the folds to the south and gave rise to the zone of shearing within which the copper lodes were formed. Dr. Dunn records an isolated outcrop of about 1 square mile of sheared

conglomerates near Udal (22° 31′; 86° 16′). They are several hundred feet thick and apparently unconformable on the epidiorite and other schists south of Udal. The age of these conglomerates is doubtful, but they are provisionally correlated with those found in south Orissa by Mr. H. C. Jones.

During the field-season 1928-29 Sub-Assistant A. K. Dey was attached to the Bihar and Orissa party for training under Dr. J. A. Dunn, in the Singhbhum district.

Gangpur State; Bihar and Orissa.

In the field-season 1928-29, an area of about 400 square miles was mapped by Dr. Krishnan in Gangpur State, Bihar and Orissa (sheet 73 B-S.W.; scale: 2 miles=1 inch). The geological succession, which is referable mainly to the Dharwar system, is substantially the same as that deduced during the previous season:—

Alluvium.
Granite, pegmatite and quartz veins.

————Post-Dharwar movements and unconformity.

Granite-gneiss (Augen-gneiss) and mica-diorite.
Epidiorite.
Sheared schistose conglomerate.
Mica schists.
Calcitic marble.
Dolomitic marble.
Mica-schists, phyllites with carbonaceous beds.
Gondite.
Phyllites.

This area is, structurally and lithologically, the westward continuation of the part of the state mapped during the previous season. It seems likely that this series may prove to be the equivalent of the Sausar series in the Central Provinces (*Rec. Geol. Surv. Ind.*, LIX, pp. 77-79), judging especially from the association and relationship of the gondites and marble beds, but the parallelism is obviously far from complete.

The axial direction of the anticlinorium is W.S.W.-E.N.E. except near the western end where it becomes S.W.-N.E. The prevailing dip is towards the S.S.E. (or S.E.) and only occasionally is a reversal of the dip to the opposite direction noticed. Some of the beds—as for example the dolomite-limestone band— are repeatedly folded in the nature of isoclines. There is clear evidence

along the western margin of this area (approximately along longitude 84° 7′, and between latitudes 22° 7′ and 22° 12′) that the structure begins to close up, as is seen in the nearly easterly dip of the schists and the considerable narrowing of the distance separating the outcrops of the conspicuous members of the series.

Along the core of the anticlinorium is a fairly thin band of gondite, marked by a number of manganese quarries. The southwesternmost outcrop of gondite is situated some 2½ miles S.W. of Ghoriajor (22° 2′ 30″; 84° 8′ 30″) and is probably the last outcrop in this region.

To the east of longitude 84° 12′ the gondite occurrences contain only quartz-spessartite rocks, but west of it the rocks show other manganiferous minerals also—rhodonite, rhodochrosite, a pale yellow slightly pleochroic pyroxene, and another beautifully pleochroic pyroxene. The last is purplish or brownish purple in hand specimens, with the following scheme of pleochroism in polarised light:—

𝔞. carmine pink.
𝔟. indigo or light purple.
𝔠. deep greenish blue.

This mineral, according to Dr. Krishnan, is probably blanfordite (cf. *Mem. Geol. Surv. Ind.*, XXXVII, pp. 125-26).

The occurrence of these silicates is thought to be indicative of a higher grade of metamorphism here than is found further east, and enables us to compare these deposits with those of the Central Provinces. This part of the manganiferous band is, moreover, economically more important than the more eastern part, as the ore is of a better type. In passing it may be mentioned that the Ghoriajor group of quarries was closed down in 1928 as the manganese bed was found to dip steeply and was hence unsuitable for the opencast working methods hitherto followed here.

At several of the gondite outcrops this rock has been definitely noted to be conformable with the phyllites and mica-schists, which form the country rock, so that the gondites form essentially a part of the sequence.

Dr. Krishnan reports that the limestone-dolomite beds, which can be traced at intervals along a line parallel with, and south of, the gondite occurrences, seem to be younger than the gondites and separated from them by a thickness of phyllites and mica-schists. This band here contains a greater amount of impurities than the

occurrences further east, and the higher grade of metamorphism seems to have converted them into calc-gneiss with tremolite, diopside, and phlogopite. The northern limb of this band, which is so conspicuous a member of the series in the adjoining eastern portion, does not occur in this area, having possibly been pinched out.

Over the greater part of this area mica-schists are the most prevalent rocks; they are partly phyllites and partly well crystallised mica-schists containing porphyroblasts of garnet, biotite, penninite, and occasionally staurolite. These porphyroblasts are frequently seen to lie at an angle to the schistosity of the groundmass, thus indicating a period of folding movement posterior to their formation—a movement which was, however, unable to rotate them enough to bring them into conformity with the new foliation imposed on the softer materials of the groundmass. Another peculiarity is that the porphyroblasts occur also in schists which are only phyllites or sericite-schists. Dr. Krishnan remarks that the presence of these larger crystals can in these cases be explained as due to the formation at a time when the rocks were subjected to conditions of a deeper zone of metamorphism than in the final stage when epi-zone conditions prevailed, the metamorphism being thus regressive. A third peculiarity is the almost universal presence—especially in the schists containing garnet—of small quantities of tiny laths of bluish pleochroic tourmaline in the groundmass. This would indicate either (*a*) that the necessary boron was deposited originally with the argillaceous sediments, or (*b*) that it was subsequently introduced by the underlying granitic masses during the course of a long series of changes to which these rocks were doubtless subjected. The former contingency merits consideration since, in several parts of the present area, the mineral occurs in schists far removed from any visible granitic intrusion. It has to be borne in mind, however, that the area may be underlain by granitic rock, as evidenced by the ubiquity of quartz veins throughout the region mapped.

Some of the carbonaceous schists contain abundant small crystals of tourmaline (micro-slides 20108, 20129), presumably formed during metamorphism. The tourmaline is a lightly pleochroic (pale orange-yellow to colourless) species, probably one poor in iron. In other cases (slides 20091, 20107) a mineral with characters near those of ottrelite was also noticed.

The sheared schistose conglomerate was seen to continue in a W.S.W. direction without a break to Tatranga (22° 7′; 84° 17′). Three isolated outcrops were found along the same strike further south-west, the last being near Amasranga (22° 1′; 84° 10′ 30″). The conglomerate was found to contain pebbles which are partly original —mainly of quartz and also of tourmaline-quartz rock—and partly autoclastic. Shearing was clearly in evidence especially along the southern part of this bed. Whether thrust-movements have also been associated with shearing, cannot at present be stated, as the region south of this zone has not yet been mapped.

Along parts of the northern margin of this area occurs a granite-gneiss with conspicuous felspar and quartz augen (sps. 40/46, 40/172), some of which are more than 1½ inches long. This gneiss conforms to the general foliation and hence must have been intruded into the original sediments, having been involved, together with them, in the post-Dharwar movements which affected the whole area. In association with, and probably intrusive into, the granite-gneiss, is a small mass of coarse mica-hornblende-diorite (sp. 40/180) occurring near Dumarbahal (22° 14′; 84° 7′ 30″).

The epidiorite sills were also intruded into the sediments at probably the same time as the granite-gneiss, as they have also been affected by the folding. They are all completely metamorphosed representatives of original basic intrusives, containing hornblende (some actinolite), orthoclase, albite-oligoclase, quartz, clinozoisite, ilmenite, sphene, and magnetite. Dr. Krishnan thinks they are very likely part of the Dalma volcanics occurring in northern Singhbhum.

In contrast with the granite-gneiss, there are granites and associated quartz veins belonging to an age posterior to the folding movements. These are distinguished from the former by the general absence of gneissic structure, the poverty of dark minerals, and the presence of granitoid texture. There are two large exposures of granite in the central part of the present area, occupying approximately 20 and 8 square miles, respectively. These are probably the equivalents of the granites of south Singhbhum and Keonjhar.

Thick mantles of alluvium occur very extensively in the southern half of this area, obscuring the solid geology.

Burma Party.

During the field-season 1928-29 the Burma party consisted of Dr. J. Coggin Brown (in charge), Messrs. G. V. Hobson, E. J. Bradshaw, P. Leicester, V. P. Sondhi, and B. B. Gupta and Dr. H. L. Chhibber.

Dr. J. Coggin Brown mapped part of Sheets Nos. 93 D/9 and D/13, lying between latitudes 20° 45′ and 21° and between longitudes 96° 40′ and 97°, comprising portions of the States of Poila (Pwehla), Pangtara (Pindaya), Mawson (Bawzaing) and Kyawktap. The adjoining sheets to the south, 93 D/10 and D/14 contain the Loi-an coalfield, examined by Dr. G. de P. Cotter in 1921-22 and mapped in part by the late Captain F. W. Walker during the same year[1]. The Kalaw ranges of the latter sheets with their enfolded Mesozoic rocks trend to the north-west and fill in the western part of the present ones around the headwaters of the Panlaung river and its tributary the Taklet *chaung*. The Tertiary deposits of the valley of Thamakan (Hsa-möng-hkam of the Shans) soon came to an end further north. The Thamakan and Heho ranges wrap around the northern extremity of the Heho plain and, continuing north through Kyawktap (20° 51′; 96° 48′ 30″), the latter forms the highlands of Mawson while the former is found again in the high ridge near Poila (20° 51′; 96° 44′ 10″). The northern extremity of the Yawnghwe plain occupies the south-eastern portion of the sheet and is separated from the Kunlon plain by a low divide. Just off the sheet on the east the great Taunggyi ridge with peaks of 5,600 and 5,800 feet completely overshadows the surrounding country, while the Mawson highlands rise like cliffs from a sea on the west of the Kunlon plains. The Zawgyi valley drains north, through the narrow upland of Pindaya (20° 56′ 45″; 96° 43′) which in its turn is bounded on the west by the wall-like escarpment of the Pindaya range. Otherwise the country consists of open grassy downs crossed by rocky limestone ridges. It possesses a karstic character and has a highly developed underground water system with its usual accompaniments of disappearing streams, cauldron valleys, pot-holes, and caves.

Southern Shan States.

The Plateau limestones which fringe the Loi-an coalfield on the east and extend under the Thamakan plain, to reappear again in the range of the same name on the east, are described by Dr. Coggin Brown as folded into gentle, approximately N.-S. trending flexures. Towards the north on Sheets 93 D/9 and D/13, the eastern bundle of these comes to an end on the southern slopes of the Mawson dome while further work is expected to prove the

[1] General Report, 1924; *Rec. Geol. Surv. Ind.*, Vol. LV, pp. 33-34.

existence of a major monocline to the north of Kyong (20° 47′ 15″; 96° 41′ 30″) which further north still develops into a fracture and forms the eastern scarp of the Pindaya range. Conditions in the eastern hills of the Mawson dome are too ill known to hazard any theory of their relationship to the plains below. The diversity of dips in the Heho ridge, the rocks of which are believed to be identical in part with those of Mawson rather than with the Plateau limestone with which they have hitherto been classified, does not lead to any useful conclusions as yet.

The formations met with have been grouped by Dr. Coggin Brown as follows :--

Alluvium and high-level pebble deposits	Recent and Sub-Recent.
Residual deposits	Ditto.
Lacustrine deposits	Plio-Pleistocene to Recent.
Upper Plateau limestone	Permo-Carboniferous.
Lower Plateau limestone	Devonian ?
Pindaya beds	Ordovician.
Orthoceras beds	Ditto.?
Mawson series	Perhaps Ordovician or Silurian.

True river-borne alluvial deposits are scarce and insignificant. The Heho plain is an old filled lake basin, the central parts of which are still water-logged and marshy. The Yawnghwe basin contains the Inle lake which is about 14 miles long and 5 miles broad. Dr. Brown remarks that there is a very intimate connection between the three valleys of Thamakan, Heho and Yawnghwe. The lowest point of the former is 4,130 feet above sea level, the heights of the other two are 3,785 and 2,915 feet. respectively. There is thus a progressive decrease of level corresponding to 345 and 870 feet from the first to the third. It appears, therefore, that the lake deposits of Yawnghwe have been continuously forming from Plio-Pleistocene times to the present day, that in the Heho valley accumulation stopped in comparatively recent times and that the Thamakan valley became dry at an earlier date. The high-level pebble beds described below prove that recent uplift has taken place.

The Taunggyi range, where it overlooks the Inle valley in the south-western corner of Sheet 93 H/1, is fronted by a well marked platform rising some 300 feet above the level of the plain. Stream-bed sections through this reveal clays, sands, and thick interbedded pebble beds. Their presence here, as Dr. Brown points out, indicates a general uplift of the country in comparatively recent times a

force which seems to have had more to do with the draining of the old lake basins than silting helped by vegetable growth, or than drainage caused by the deepening of the exit channels through limestone solution in the normal progress of events.

The universal mantle of red clay, which covers the lower parts of the areas occupied by limestone, accumulates in all situations possessing a gradient sufficient to retain it during the rainy season, and gives the country as a whole, with the exception of the rocky ridges, a very mature appearance. It differs in no way from the 'terra rossa' of the Northern Shan States. Its thickness varies greatly from a few feet on the lower slopes to as much as 30, 40 or 50 feet in the hollows. It is carried down the underground water circulation channels into joint and fracture planes, into solution cracks and cavities and is then found in mining operations at depths of hundreds of feet.

There are numerous more or less level expanses of residual soil at considerable elevations. The smaller ones in valleys of enclosed drainage originate, according to Dr. Coggin Brown, through the blocking of the inlet funnels into the underground circulation system. In some of the larger ones the former existence of lakes is suspected but not proved. The gradual creep of soil and clay from surrounding hills results in the blanketing of the lower slopes, and in the gradual merging of deposits but little removed from their original situation with materials which have probably been transported from greater distances.

Mr. C. S. Middlemiss was the first geologist to draw attention to the elongated outcrops of late Tertiary lacustrine deposits amongst the strata of his Great Limestone zone.[1] They are coarse loose conglomerates and pebble beds with banks of sand-rock, clays, and loams. They are horizontal or with only insignificant dips. The best examples exist in the Thamakan valley and they do not appear to extend as far on to Sheets 93 D/9 and D/13 as has been previously supposed.

Representatives of both sections of the Plateau limestone occur on the sheets, but it did not seem possible to Dr. Coggin Brown to map them separately. The rocks of the Thamakan range and its extensions to the latitudes of Poila and Kyawktap belong to this formation. Typical brecciated dolomites occur near Kyong. The western boundary was found in traverses to the west of Poila and Pindaya

[1] General report for 1899-1900, page 147.

where the group forms a narrow band at the foot of the Pindaya range, stretching north and south and giving place to the older Ordovician rocks further west. On the east it abuts against the older rocks of the Mawson highlands but the exact boundary is obscured by great spreads of thick residual soil. The occurrence of *Fusulina* sp. just to the east of Pindaya and of *Lyttonia* sp.[1] with clisiophyllid corals near Nyaungkaya (20° 54′ ; 96° 46′ 30″), proves that the limestones hereabout belong to the upper or Permo-Carboniferous section of the Plateau limestone. When these rocks are unfossiliferous it becomes a difficult matter and sometimes an impossible one to differentiate between them and the older limestones of the Mawson beds. In the extreme north, *i.e.*, beyond Kyauksu (20° 58′ 45″; 96° 44′ 15″) the area has not been examined and it is not known what happens to the band in that direction.

The name Pindaya beds has been given by Dr. Coggin Brown to the rocks which build the Pindaya range between the band of Permo-Carboniferous limestone which forms the frontal scarp, overlooking the Pindaya valley on the west, and the crest of the range, as far as it has been traversed, to about longitude 96° 40′. After ascending the first steep scarp a gentler sloping platform is reached where the calcareous shales, slates, and bands of argillaceous limestones of this group are found. In the southern traverses about Poila and Ye-o-sin (20° 53′ 30″; 96° 42′ 15″) shales, slates, and mudstones are more frequent than in the northern traverses between Pindaya and Zawgyi. In both parts, however, there is a marked development of limestone horizons, generally a hard, massive, bluish-grey, calcite-veined rock, often bearing patches and seams of argillaceous matter and sometimes containing well laminated but contorted marly bands. These rocks form the characteristic light brown soils of the higher parts of the range and have given rise to the intricate system of small cauldron valleys which everywhere scar its surface. The rocks as a whole dip S.E. and E.S.E., under the outer and younger Permo-Carboniferous band, though there are evidences of folding, confined to themselves, further west into the range. The only locality which has yielded identifiable organic remains is between Ye-o-sin and Wa-bya (20° 53′ 25″; 96° 41′ 15″) where the mudstones are fossiliferous and the brachiopoda are taken provisionally to indicate a Lower Naungkangyi age.

[1] Determined by Dr. Stanley Smith of Bristol University.

Fossiliferous Naungkangyi rocks have also been found by Dr. Coggin Brown on Sheet 96 H/1, near Sale (20° 48′ ; 97° 1′) where blotched brown and light red mudstones contain badly preserved remains of cystidean plates, fragments of trilobites, and small *Orthidae*.

The Orthoceras beds form the greater part of the western limb of the Mawson anticline. Dr. Coggin Brown reports that they are generally hard, flaggy, pink, purple or reddish argillaceous limestones, with a peculiar 'augen' structure which on weathering causes them to develop a characteristic pattern resembling that of crocodile hide. They recall the 'knollenkalk' of German authors. They often contain large crinoid stems and numerous specimens of *Orthoceras*. Good sections of these beds are displayed in the valley to the east of Pawmye (20° 58′ ; 96° 46′ 15″) and on the flanks of peak '4,613' N. E. of Nyaungkaya. In the former locality they seem to be underlain by yellow sandy mudstones with badly preserved and indeterminable fossils not unlike Naungkangyi remains. They sometimes pass into thinly bedded, calcareous shales, generally very contorted or sheared but often containing bent and broken specimens of *Orthoceras* sp.

This cephalopod is common in the Nyaungbaw limestones of the outer platforms of the Northern Shan plateau while there are accounts of these and similar rocks, particularly in the earlier writings of LaTouche and P. N. Dutta, which would apply to the beds under description. The Nyaungbaw beds form the uppermost division of LaTouche's Ordovician system, but taking into consideration the extended time range of *Orthoceras* and its cosmopolitan character together with the notorious tendency of the Naungkangyis to rapid lateral lithological changes, Dr. Coggin Brown prefers not to attempt any correlation of these Orthoceras beds with distant determined horizons until they have been examined more fully.

The Mawson series forms the eastern part of the Mawson highlands and its true relationship to the rocks just described is not at present apparent. There does not appear to be any marked unconformity between them, but both this and the further question as to whether the Mawson dome is faulted along its crest must be left for more detailed mapping in the hope that sections will be found where the crucial junction zones are not hidden. The interpretation of the geology of this region consists in attempting to

join together small, isolated and generally unfossiliferous rock exposures separated by large expanses of residual soil, thick enough to hide the underlying strata completely, and in no case is this more evident than in the present one.

There are, however, differences which make it necessary, in Dr. Coggin Brown's opinion, to separate the rocks of western Mawson from those on the east. The 'augened' limestones, slates, and sandy shales give rise to a definite type of topography different from that of the west, where thick limestone bands, separated by a few strongly developed sedimentary beds, persist across country in a way the others do not. These limestones form escarpments in the east which are wanting in the west and it is from their presence that the placing of a sketchy boundary line has been attempted on the map. They are usually homogeneous, light greyish blue or brown, hard, compact, calcite veined, finely crystalline rocks and have yielded no fossils except a single specimen of *Orthoceras* sp. from Singaung (20° 56′ 30″; 96° 49′), while the arenaceous shales which lie between them have only yielded one specimen of a brachiopod, a member of the *Strophomenidae* family probably related to the genus *Schuchertella*, from Theingon (20° 56′ 15″; 96° 50′ 15″).

The series continues south and probably forms most if not all of the Heho range. The lead-silver ore deposits of Mawson lie very largely but not entirely within these rocks (*see* 'Lead and Silver').

Messrs. G. V. Hobson and P. Leicester were deputed to continue the geological survey of the Northern Shan States from latitude N. 23° 15′ in a northerly and north-easterly direction to the Chinese frontier. Mr. Leicester was given the western half of sheet No. 93 E/7, the main object being to map the contact between the Tawngpeng granite and the Chaung Magyi series. He was, however, transferred to the Amherst district in February, by which time he had traced the granite boundary as far as longitude E. 97° 25′.

Northern Shan States.

Mr. Hobson commenced work on Sheet 93 E/7 to the east of the Nam Tat and completed the survey of this sheet to the east and north-east and also the north-western half of Sheet 93 E/11, a total of about 250 square miles. He found that the belt of Palæozoic sediments running roughly north and south across Sheet 93 E/8 passes on to Sheet 93 E/7 but at once makes a turn to the

north-east and diminishes very considerably in width. These sediments form a range of hills in marked contrast to the topography of the Plateau limestone to the south-east. The Plateau limestone forms a fringe along the foothills of the above range and is then covered with younger sediments mainly of Rhætic age. This covering is much more complete than appears to be the case further south, and suggests that the marine transgression was from the north-east, *i.e.*, from Yunnan. The occurrence of a series of unfossiliferous dark grey, thin-bedded limestones with interbedded sandstones, passing up into carbonaceous sandstones, is reported from between the Plateau limestone and the Rhætic beds. Mr. Hobson tentatively calls these rocks the Passage beds and suggests a possible Noric age on the grounds of analogy with rocks in Yunnan. At one point only a muddy limestone was found containing typical Jurassic brachiopods as described from the Namyau series.

Mr. Leicester traced the granite boundary mapped by Dr. J. Coggin Brown in the sheet to the south from a point one mile west of Tunswe (Tunhso) village (97° 17′ 25″; 23° 15′ 30″) northwards to Loi-hsawng (97° 18′ 14″; 23° 20′ 35″) where it becomes irregular and eventually sweeps east-north-eastwards south of the Loi Lem ridge to where it crosses the main caravan route from Namhai (Mongmaw) to Nam Kham, two-and-a-half miles south of Oi-Law village (97° 26′ 40″; 23° 28′ 2″).

The granite is a simple biotite variety with orthoclase in excess of plagioclase. In places it is traversed by small veins of tourmaline but the most striking feature of the area is the remarkable degree of its sericitisation in certain places. Around Kawnghsong (97° 16′ 31″; 23° 19′ 15″) the granite is altered into a quartz-sericite-schist over an area of nearly four square miles. Microscopic examination of thin slices of the schist shows two main types :—(*a*) a coarse variety consisting of large crystals of quartz in a groundmass of sericite laths and quartz and (*b*) a finer variety composed of a fine aggregate of fibrous sericite and quartz. The rock weathers into rounded grey boulders which strongly resemble granite at a distance but the white scars of slips on the hillsides betray the presence of the schistose rock. Other areas exist on the northern slopes of Loi Lem, south of Man Sak (97° 21′ 30″; 23° 26′ 47″), around Nawngput (97° 24′ 3″; 23° 28′ 23″) and elsewhere to the north-east. It is interesting to note that the

sericitised granite is associated in many cases with intrusions of basalt and amphibolite and that the granite is traversed by numerous faults, the fissures of which are filled with quartz.

The Chaung Magyi series borders the granite to the south and east and is here composed of quartzites, sandstones, slates and shales. Where the rock is not fresh it is difficult to distinguish the sandstones and shales from the unfossiliferous representatives of the newer formations which rest upon them. In the metamorphic aureole, however, bordering the granite, the Chaung Magyis are converted into hard quartzites, sometimes felspathic, and micaceous slates and phyllites.

In the south-west of the sheet the Pangyun beds border the Chaung Magyi series along the boundary of a distinct fault which runs from south-west of Penglun village (97° 18′ 48″; 23° 14′ 47″, Sheet 93 E/8), across the ridge just south of this place and north-eastwards towards the southern end of the limestone peak of Loi Kyaktaw, 6,198 feet. The belt of Pangyun beds is here less than a mile broad and is overlain by a narrow band of fossiliferous Naungkangyi beds upon which rest the Namhsim sandstones.

Two outliers of Plateau limestone were mapped north of the Penglun outlier, also a small outcrop of limestone on the Chaung Magyi-Pangyun fault line where this cuts the track between Pangnang and Pangkaw.

After working in the Northern Shan States Mr. Leicester was deputed to continue his work in the Amherst district where he mapped parts of Sheets 95 E/13 and E/14 before going on leave. The Taungnyo range, which is composed of sandstones, quartzites, shales, and slates, continues southwards and terminates in the southern portion of Sheet 95 E/13 where it meets the northern boundary of the granite boss which sweeps inland east-south-eastwards from the coast.

Amherst District.

The granite is for the most part a normal medium-grained biotite variety and resembles that of the coast near Amherst. Inland on the densely wooded slopes of the granite ridges exposures are naturally neither so plentiful nor so clear as on the coast, but as the sedimentaries are approached the banded and gneissic structure so characteristic of the coastal granite becomes evident.

Hornblende-biotite granite (adamellite) with accessory sphene and epidote occurs south-east of Sakangyi (97° 47′ 12″; 15° 50′ 31″)

and in other places. Within the metamorphic aureole the biotite-granite frequently contains tourmaline and veins of tourmaline, and micro-pegmatoid rock ; in places it carries quartz stringers with grey and greyish-brown cassiterite.

As the contact with the sedimentaries is approached a belt of very characteristic metamorphic rocks appears consisting of augen-gneiss and banded granulite. Mr. Leicester described these as the typical metamorphic rocks of the northern part of the Amherst district.

The augen-gneiss usually consists of quartz, orthoclase, and microcline with a little subordinate plagioclase and biotite in the form of whisps which sweep round the contorted crystals of quartz and felspar. The granulite is a finer-grained rock which when weathered strongly resembles a schist. It usually contains magnetite and often small pink garnets while in places a hornblende variety is found.

Near the granite boundary the sandstones and shales of the Taungnyo range give place largely to quartzites and slates, strongly resembling the rocks of the southern part of the district in the Ye-Lamaing township, which are continuous with the rocks of the Mergui series of Tavoy.

Within the area surveyed Mr. Leicester was able to examine carefully a few contacts between the Moulmein limestone and the sandstone-shale series. In spite of considerable faulting in many places it was possible to establish that the Moulmein limestone overlies the sandstones and shales of the Taungnyo range, for which Mr. Leicester suggests the name Taungnyo series, after the range of hills on which they are so well exposed. Whether or not there is any considerable unconformity between the two formations it is at present impossible to say, but in view of the evidence already obtained, Mr. Leicester is inclined to believe that there was no great lapse of time between the deposition of the shales comprising the upper beds of the Taungnyo series and the limestones.

Should this prove to be true it would be necessary to assume either that the Taungnyo series is younger than the Mergui series or that in reality the Mergui series is of more recent age than at present assumed, its greater degree of metamorphism being due to the extensive granite intrusions of the country to the south. If also, as seems probable, the Moulmein limestones are overlain by Permo-

Triassic beds corresponding to the sandstones and shales of the Martaban group, the Taungnyo series may eventually be found to comprise an unbroken sequence of sedimentaries ranging from early or pre-Carboniferous times to the Trias.

Close to Lutshan village (97° 54′ 1″; 15° 47′ 34″) are three outliers of massive blue and grey limestone, two of which are seen overlying the shales and slates of the Taungnyo series.

The largest outcrop of the limestone is that of Lutshan Taung which on three sides rises precipitously above the laterite and alluvium of the plain. Dip-slip strike faults may be seen running north and south through the limestone and the western end of the outcrop is bounded by a fault with a downthrow to the east, bringing the limestone, which dips between 30° and 40° eastwards, against the slates of the Taungnyo series which have the same strike but a steeper dip of 55°. Here the different dips suggest an unconformity but the actual line of contact is obscured by talus and the quartz contained in the fault fissures.

The outcrop to the west, situated on the eastern slope of Kamawseikto Taung, is also traversed by faults and in places great slabs of limestone may be seen dipping steeply eastwards but not so steeply as the underlying shales which are here nearly vertical. At the highest point at the north-western end of the outcrop, however, there is no evidence of a fault and the limestone may be seen in contact with slates dipping conformably with it at 74° to the east.

The limestone on the southern face of this outcrop is much sheared and slickensided and the mapping suggests a dip fault of considerable extent.

A point of interest is that in a small cave in the southern face of Lutshan Taung a number of stalactites may be seen hanging at 35° from the vertical. This phenomenon indicates that the limestone has been tilted northwards since the formation of the stalactites, possibly by comparatively recent slipping along old fault planes.

In the neighbourhood of Tanyin (97° 57′ 12″; 15° 44′ 21″) Mr. Leicester again observed contacts between the calcareous rocks and the arenaceous-argillaceous series. In the main ridge west of Tanyin the quartzites and slates have a N.-by-W. strike with a steep easterly dip and at Lay Pho Taung, about half a mile south-west of Tanyin, the Moulmein limestone may be seen

dipping eastwards at 60° with a strike N.30°W. At the northern end of the hill slates may be seen on either side of the limestone but the actual contact is obscured.

One-and-a-half miles east of Tanyin is the long steep range of Beke Taung, composed of massive blue and grey limestone with a strike N.5°W., and a westerly dip of 65° where it disappears beneath the laterite of the central plain, which here becomes narrower and eventually gives place to hilly country to the south. In the stream bed east of Beke Taung the contact of the limestone with the slates is again visible. Both have the same steep westerly dip and are crushed and contorted. The actual line of contact is wavy and the two series have obviously been folded together. The limestone at the base passes into a cleaved calcareous shale and in the absence of evidence of a fault at the contact there appears to be little if any unconformity.

The Beke Taung range comes to an end about a mile north of the pass east of Tanyin but is continued northwards by another ridge half-a-mile to the east and it seems probable that this break in the ridge may be accounted for by a strike-slip dip fault similar to that at Lutshan. At the western side of this ridge both the limestone and the slates and quartzites have a N.-S. strike and vertical dip.

Mr. Leicester considers that no definite conclusions can be reached regarding the relations of the Taungnyo series and the Moulmein limestone until further contacts have been examined and he believes that two traverses across the Amherst district from west to east, one in the north and the other in the south, would greatly assist in the elucidation of the stratigraphy of the district and simplify the mapping of the individual sheets.

As already stated, the evidence at hand proves only that the Moulmein limestone overlies the sedimentaries of the Taungnyo range, but it seems probable that the limestone is overlain by higher beds of the series which will eventually be correlated with the Permo-Triassic rocks of the Martaban group lying beneath the laterite of the central plain. The successive limestone ridges would belong to the same band thrown up by a series of folds. The easterly dip of the limestones on the west, the westerly dip of the Beke Taung limestone and the similar dip of the quartzites and slates suggest a syncline beneath the plain. That arenaceous rocks do occur beneath the laterite of the plain has been proved

by the series of borings described in a paper by Mr. Fryar on exploration for coal in the vicinity of Moulmein.[1]

There is at present no direct evidence of any great unconformity between the Moulmein limestone and the Taungnyo series and the change observed in the direction of dip from arenaceous through argillaceous to a calcareous facies is one consistent with the conditions to be met with in a gradually deepening sea. The isolated occurrences of limestone on the slopes of the Taungyo range can be accounted for by faulting assuming the limestone resting upon the upper beds of the series to have been denuded elsewhere.

In the course of his survey Mr. Leicester discovered a small cave in the eastern side of Naungkwe Taung (97° 55′; 15° 50′) with a bone bed, varying from a few inches to four feet thick, lying between the limestone floor and a covering of stalagmite from eight inches to several feet thick. The bones are very plentiful but mostly fragmentary and lie in great disorder in a matrix of reddish-brown earth. A large amount of material has been removed by the local villagers who were under the misapprehension that they would find buried treasure, but a considerable quantity of material remains to be excavated. Mr. Leicester made a collection of bones and teeth which have been identified by Dr. Pilgrim and Miss Bate of the British Museum as belonging to species of bear, pig, ox, deer, and antelope.

Occurrences of grey and greyish-brown cassiterite in the lateritic talus of Mawpalaw Taung were examined where they have been mined at Thetkaw (97° 46′ 26″; 15° 52′ 28″) and near Sakangyi (97° 47′ 12″; 15° 50′ 31″) and Mr. Leicester observed the occurrence of black cassiterite in a thin pegmatite vein at Kunhnitkway (97° 51′ 36″; 15° 48′ 22″) where the ore is washed from the much kaolinised pegmatite during the monsoon.

Dr. H. L. Chhibber resumed the survey of the Jade Mines region and mapped parts of Sheets 92 C/5, C/6, C/10 and C/H, recognising the following series and rock-types :—

Myitkyina District.

X. **Alluvium.**
IX. **Volcanic rocks.**
VIII. **Gabbro.**
VII. **Tertiaries.**

[1] Geological Papers on Burma, page 460. 'Exploration for coal in Moulmein Fryar.'

VI. Crystalline complex.
V. Highly altered picrites (epidote-rocks) with volcanic tuffs.
IV. Jadeite-albite dykes.
III. Peridotites and serpentines.
II. Granite.
I. Limestone.

Geological mapping in this area has to be carried on under trying conditions owing to the trackless nature of the forest-covered hills. The colour and other physical characteristics of the limestone are as described last year. Where it has been invaded by granite, however, it has altered to white, coarsely crystallised marble, in which numerous contact minerals are developed, including graphite, forsterite partially altered to serpentine, phlogopite, garnet (hessonite), crystalline silica, small pink or reddish octahedra of spinel, a few small deep red rubies, and pyrrhotite. Dr. Chhibber believes that this white marble, with its associated contact minerals, has been formed by the thermal metamorphism of the dolomitic limestone of the area and that the fossil organisms, which he found in the bedded limestone, prove its sedimentary character and the organic origin of the graphite. The occurrence of gems is localised and they are found in pockets only.

Granite occupies almost the whole of the south-eastern portion of Sheet 92 C/10, west of the Namya and Indaw *chaungs*. Its continuation west of the Indaw was traced as far as the deserted village of Hkohka (25° 27′ 48″: 96° 38′ 26″) and Jumgahtawng (25° 28′ 58″; 96° 36′ 26″) and it apparently extends further south still. It builds either small groups of thickly forested hills, sometimes rising 1,500 feet above the surrounding plain, or forms scattered bosses and tors of smaller size. The original intrusion must have occurred in the form of a batholith. The rock shows various shades of pink and grey and its texture is generally medium-grained. In places it has a foliated or banded appearance. The predominant type is a biotite-potash-granite with the following varieties :—(1) biotite-muscovite-granite, (2) hornblende-granite and micro-granite, (3) graphic granite, (4) micrographic granite, (5) quartz-augite-monzonite, (6) quartz-biotite-monzonite, and (7) basic segregated patches of diorite. In the monzonites quartz occupies only a subordinate position with orthoclase and plagioclase occurring in almost equal proportions; the latter is mainly oligoclase but in places it is oligoclase-andesine. In one case augite

and in another biotite are the only ferro-magnesian minerals present. In places the granite is permeated with veins of graphic granite and quartz. Dr. Chhibber concludes that the granite intrusions took place during the Mesozoic era.

The outcrop of altered peridotites and serpentines mapped last year continues as far north as the Sanhka Hka (92 C/5). Another outcrop on Sheet 92 C/6 forms hills '1,448' and '1,669.' The same rocks are seen again slightly east-north-east of Kansi forming hill '2,162.' In the south a small outcrop of these rocks was observed in the Hkakon Hka (92 C/11), about ½ mile west of the first bridge in the 22nd mile of the Mogaung-Kamaing road. The rocks build plateaux, conical hills, and well-defined ranges. The original intrusions probably took place in the form of a big batholith. Serpentinised dunite was the commonest variety collected this season. Specimens of serpentine-breccia were collected from the right bank of the Mabaw Hka, close to where the Lonkin-Kansi path crosses the stream. It is concluded that these intrusions took place in post-Permian and pre-Peguan times and that they probably belong to the same group which extends from the Andaman islands in the south to the Naga hills in the north, the age of which is surmised to range from late Cretaceous to early Eocene. The argument for the contemporaneity of these different occurrences rests on their significant linear distribution and their remarkable petrographic similarity.

Highly altered picrites (epidote-rocks) with andesitic tuffs first make their appearance a little west of the 17th mile on the Kamaing-Tawmaw road and continue to about 2¼ furlongs east of Namting (25° 38′ 45″; 96° 27′ 29″); on them deep red soil forms a thick mantle. These rocks are characterised by the presence of felspar and quartz with abundant epidote, while these minerals are absent in the typical serpentines or altered peridotites exposed on the west. The commonest type is an epidote-rock (epidosite) with which andesitic and other highly altered tuffs are associated. In places small outcrops of andesites and basalts were noticed, while elsewhere the rocks were observed to be permeated with doleritic and siliceous injections.

The crystalline schists forming the crystalline complex described last year[1] terminate on the east a little west-south-west of the Lama (25° 42′ 22″; 96° 21′ 15″). On the west the range of hills

[1] *Rec. Geol. Surv. Ind.*, Vol. LXII, 1929, pp. 110-111.

in the north-western corner of Sheet 92 C/6, on which the points '3,134' and '3,044' are marked, is composed of these rocks. They crop out again in the Sanhka Hka (92 C/5) and probably extend much further northwards. Specimens of spotted epidiorite, graphite-schist, quartz-schist, glaucophane-schist, spotted actinolite-zoisite-schist, and idocrase-schist, are very common in the collections made this year. Idocrase is a common constituent, especially of those schists collected from the vicinity of the limestone. Injections of mica-pegmatites (with aplitic veins) and numerous quartz veins also occur in these rocks. They have been thrown into anticlinal and synclinal folds and not infrequently fairly high cleavage angles are to be observed. At their junction the altered spotted epidiorites were seen dipping E. S. E., away from the serpentines in the Sanhka Hka (92 C/6).

Along the Uru valley the Tertiaries were mapped as far as the Uru Hka, about 1¾ miles north of Kansi (25° 47′ 1″; 96° 22′ 48″). West of the Namjan Hka the Tertiaries build hills over 3,000 feet high. Their composition has already been described in the last Report.[1] Boulders of glaucophane-schist and other schists, diorite, basalt, dacite, silicified breccia, epidiorite and hornblende-lamprophyre were seen associated with the rocks in question. In the immediate neighbourhood of Kamaing (25° 31′ 40″; 96° 43′ 4″), inclined pebble-beds were observed on the motor road; these may be the equivalent of the Plateau gravels of other parts of Burma.

On lithological grounds the Tertiaries may be tentatively classified into two subdivisions :—

(1) Sandstones and shales, east of the Uru river.

(2) Boulder conglomerate with minor development of sandstones and shales, west of the Uru river.

Such a development of the Tertiaries is thought by Dr. Chhibber to shew that currents both from the north and west must have participated in their formation, those coming from the west having been torrential streams which deposited the boulder conglomerates. Small stumps of fossil wood comprising both palms and dicotyledons were found a little south-east of Namyong (25° 40′ 31″; 96° 26′ 17″). The inner portion of some is carbonised and the outer silicified.

Gabbro first appears about 1¾ miles west-south-west of '△ 5,124' (92 C/5) in the Namjan Hka, which has cut a gorge with steep

[1] Rec. Geol. Surv. Ind., Vol. LXII, 1929, pp. 109-110.

cliffs as far as its junction with the Loimye Hka. From the latter point the rock ascends into the hills east of the stream and is overlain by the volcanic deposits of Mount Loimye. A little over half-a-mile north of 'Δ 5,124' it again makes its appearance forming the hills '4,842,' Bum-i-Bum, and '4,858' (92 C/5), while its northern extension was traced as far as the confluence of the Dabbum and the Chinkichu Hka. The gabbro here was seen to be intrusive into the Tertiaries and in places the *lit-par-lit* phenomenon was evident. Sometimes it is very finely bedded and towards its western boundary easterly dips were mostly observed. East of the Namjan Hka, north of its tributary the Loimye Hka, the gabbro comes in contact with greenish black basal tuffs, the latter most probably marking the position of one of the older vents which served as passages for the uprise of the gabbroid magma. The form of intrusion near the western margin appears to be that of a concordant inclined sill. The predominant rock is a massive, coarse quartz-gabbro, but various modifications such as quartz-enstatite-gabbro, micrographic gabbro, etc., were noted.

The volcanic rocks of the area consist of the Mabaw siliceous agglomerate, of the andesite and basalt outcrops in the neighbourhood of Namyong, and of the Loimye volcanics. The Mabaw siliceous agglomerate begins near Sanhka village and continues in a north-easterly direction for about three miles as far as the Moschen Hka. It forms a red or yellowish-red bedded deposit with large blocks of siliceous breccia. Dr. Chhibber considers that the volcano burst through the floor of the serpentine, since fragments of the same are included in the breccia. Moreover the reddish colour of the paste confirms the view that it must have been derived from the soil or subsoil of the serpentine. In places, by further concentration, the ferruginous material has been converted into iron ore. It is concluded that the volcanic eruptions were subaqueous and contemporaneous with the deposition of the Tertiary strata.

Seven outcrops of hornblende-and hornblende-augite-andesite and three of basalt were mapped in the neighbourhood of Namyong. The biggest outcrop of typical hornblende-andesite is that of the Janmai Bum, (hill '1,668'. 92 C/6). A very dark compact picrite-basalt with phenocrysts of olivine and augite occurs about ¼ mile east of Namyong on the old road to Nanyaseik. A similar rock was described last year and this outcrop most probably marks its source. About a mile south of Namyong the upper portion of

hill '1,371' is built of olivine-basalt. Mention may also be made of similar basalt, less than three furlongs S.W. of Nsengahtawng (25° 40′ 8″; 96° 25′ 52″).

It is concluded that all these eruptions took place in late Tertiary times and their contemporaneity with similar rocks in the Lower Chindwin and Mount Popa areas is probable. Mount Loimye, being the highest point, forms a conspicuous landmark in the Kachin hills. It is a breccia and lava dome, 5,124 feet above the sea and is 25 feet higher than the celebrated Mount Popa. The history of the volcano is divided by Dr. Chhibber into four stages :—

(1) Black basal tuffs of aqueous origin, interbedded with the Tertiaries and metamorphosed by the intrusion of the gabbro.

(2) Flows of basalt and andesite. As many as five flows were recognised between the levels 3,550 feet and 3,800 feet on the spur south of 'Δ 5,124.'

(3) Volcanic breccia with finely bedded, sometimes laminated, consolidated ash or tuff.

(4) Andesitic and basaltic breccia building up the dome of Mount Loimye. This marks the most active and longest phase.

A complete record of the history of the volcano is preserved on the spur south of the Loimye Hka, while (2), (3) and (4) are seen on the southern spur leading to the Chaobadu Bum. Only (3) and (4) were observed north of 'Δ 5,124.'

Shwebo District, Burma.

Mr. V. P. Sondhi resumed his survey work in the Shwebo district, completed Sheets 84 N/1, N/5, N/9 and mapped a large part of Sheet 84 N/13 together with a part of the area lying west of the Irrawaddy in Sheet 93 B/1. He recognised the following series and rock types :—

Alluvium.

Irrawadian series.

Pegu series.

Dolerites.

Basalts.

Metamorphic rocks (Mogok series).

The greater part of the area surveyed forms the catchment of the river Mu, which runs due south, along a meandering course, through the centre of its broad shallow valley along the eastern margin of Sheet 84 N/5. On both sides it is bordered by broad stretches of alluvium extending from 12 to 16 miles east and west of the river, both of which give place to the more broken country of the Irrawadian series. The latter consists of a loose, incoherent, sandy deposit and covers practically the whole of Sheet N/1 west of the alluvium, and a large part of Sheets N/9 and N/13 east of it. A remarkable feature of the series in Sheet N/9 is the existence of numerous small mud springs east of Kin-u (22° 46′; 95° 37′ 23″). occurring either singly or in clusters of two to six little 'pseudo-craters' with diameters varying from two to eight feet. The fine slushy mud that oozes out from the top, forms low crater-like mounds while the accompanying water leaves on evaporation a white crust of alkali salts on the surrounding surface.

In Sheet N/13 the series shows a marked change in its lithology and its mode of deposition. It consists here of distinctly bedded sandstone and sandrock, occasionally containing beds of sandy shale. Towards the north-western quarter of the sheet, in the vicinity of the villages of Myemun (22° 59′; 95° 47′ 30″) and Tayawgaing (22° 54′ 30″; 95° 47′) the rocks assume the characters of deeper water deposits and consist of calcareous sandstone, shale, and thin beds of arenaceous limestone in the form of an inlier in the sandstone. This inlier has been separately mapped and has been tentatively referred to the Pegu series on account of its great lithological resemblance thereto. East of the inlier the deposit is undoubtedly Irrawadian though very different in character to that found on the west. It continues to the eastern end of Sheet N/13 and covers a large portion of the area surveyed in Sheet 93 B/1. Near the eastern end the beds are greatly disturbed and are cut through by dolerite which is exposed in various outcrops in the form of long dykes as well as minor intrusions. Specimens collected from different outcrops are very similar to each other in their mineral constituents and mineral inter-relationships, which suggest that they belong to the same parent magma. A few outcrops of a highly decomposed amygdaloidal basalt were noted interbedded with the sandstone, showing that the volcanic activity began during the Irrawadian period and continued periodically till after their deposition was completed.

East of the Irrawadian sandstone a narrow strip of the Pegu series, consisting of hard shales and calcareous sandstone, runs north and south for a short distance. In these rocks poorly preserved fossils were discovered at two localities, and proved to be casts of gastropods and *Batissa* sp., cf. *kodoungensis*, in one case and *Balanus* sp., *Turritella* sp., and *Batissa* sp. in the other. These rocks are tightly folded and are faulted against the metamorphic rocks of the Mogok series, which here consists mostly of a bluish grey dolomitised limestone with green, fine-grained schist.

Lower and Upper Chindwin Districts.

Mr. B. B. Gupta continued his work of previous years, completed a small area in the north-west corner of Sheet 84 J/10 and finished the survey of Sheets 84 J/9 and J/13, which include parts of the Shwebo, and Upper and Lower Chindwin districts.

Almost the whole of Sheet 84 J/13 is covered by Irrawadian sandstone, with the exception of a small inlier of Pegus, about seven miles long and five furlongs broad, and a small area of gravels (? Plateau gravel) near Laungbyit (22° 54′ 30″; 94° 45′). The Irrawadian rocks are characterised by the usual friable brownish sandstone, associated in some places with greyish tenaceous clay generally mottled red by weathering. Lenticles of shales and concretions of sandstone were noticed in several places.

Vertebrate fossils were collected from two localities:—(1), 1 mile and 3 furlongs N. N. W. of Taungbyinnge (22° 50′ 30″; 94° 49′ 30″) and (2), 1 mile W. S. W. of Aukyedwin (22° 52′ 30″; 94° 50′). They were found at the base of the Irrawadian, not far from the Pegu-Irrawadian boundary. Two of the specimens from the second locality have been referred by Mr. Hopwood of the British Museum, to the genera *Mastodon* (*Tetralophodon*) and *Stegolophodon*. Fossil wood is plentiful in some localities; beautifully preserved opalised specimens were noticed in the Nabok *chaung* about three miles N. N. E. of Thanbauk (22° 57′; 94° 45′).

The Pegu rocks of the area form an inlier and are represented by bedded, sometimes very compact, medium-grained sandstone interbedded with argillaceous rocks of no great thickness. These argillaceous beds often assume a chocolate colour on exposed surfaces and look not unlike marls of the same colour in the Pondaung sandstone group. Selenite was noticed near Taungbyinnge and casts of mollusca were found about one mile N. N. W. of the same

place. Very few dips, generally varying from 12° to 25°, were observed in the Irrawadian, which is the predominant formation in Sheet 84 J/13. In the Yede *chaung* the beds are horizontal, but very high and even vertical dips were seen close to the faulted area. There are indications of folding in the Nabok, Thanbauk, and Khwedabu *chaungs*.

Four faults were noticed. The largest in the sheet is near Taungbyinnge and forms the boundary between the Pegu and the Irrawadian for some distance before cutting through the younger formation. It was traced as far north as two miles east of Saga (22° 57′ 30″; 94° 50′ 15″), while in the south it was seen to extend a little beyond latitude 22° 48′ 40″. Another fault occurs at the junction of the Taunggyin and Nyaungthabye *chaungs*, running in a north-north-easterly direction almost parallel to the large one just described.

A third fault was seen in the tributary of the Ngongyaung *chaung*, about four miles S. S. W. of Taungbyinnge. It was traced for a distance of half a mile, parallel to the direction of the first fault. The fourth fault cuts through the Pyaw and Hlainggaung *chaungs* in a north-easterly direction.

In Sheet 84 J/9, besides the Natma beds (*Rec. Geol. Surv. Ind.*, Vol. LXII, pp. 105-107), the Irrawadian, Pegu, Yaw, and Pondaung beds are exposed in regular sequence. 'Plateau gravels' were seen west of Kin (22° 46′; 94° 42′) and near Kyaukkedet (22° 57′ 30″; 94° 43′ 30″), and 'red earth' was noticed south and south-west of the latter village. The lithological characters of the principal rocks do not seem to have undergone any change from those seen in the adjoining southern sheets, with the exception that in river sections, some of the argillaceous beds of the Pegu formation were tinted red on exposed surfaces. All the formations were barren of fossils and no light was thrown on the exact age of the Natma beds.

The strike fault forming the boundary between the Pondaungs and the Irrawadian series, mentioned in the reports of previous years was traced as far north as latitude 22° 52′ 30″. An asymmetrical anticline was found in the Pondaungs with the shorter arm on the east. The dips are very high near the fault line, gradually sloping more gently on the west. The Natma beds become attenuated and finally disappear at about latitude 22° 52′. Owing to the pitch of the axis of the fold the outcrops of the various formations other

than those of the Irrawadian rocks die out in the north. The portion of Sheet 84 J/10 which was mapped this season was found to be covered by Irrawadian rocks.

Resident Geologist, Yenangyaung Oil-field.

During six months study leave in 1928-29 Mr. C. T. Barber visited the United States of America to study the methods of the United States Bureau of Mines and to acquaint himself with the most recent American oil-field practice. During the five months spent in the United States Mr. Barber visited the offices of the Petroleum Division of the Bureau of Mines at Washington, D. C.; Bartlesville, Oklahoma; Laramie, Wyoming; San Francisco, California; and Dallas, Texas. At Bartlesville, the experimental station of the Petroleum Division of the Bureau, the recovery and other experiments of the Bureau were studied, while at Laramie, San Francisco and Dallas the methods of the officers of the Bureau in conducting their major field studies were observed. In California also, the supervisory functions and methods of the United States Geological Survey and the Oil and Gas Division of the State Mining Bureau were studied. In addition to these investigations the principal fields in the Mid-Continent, Rocky Mountain, Southern California, and West Texas areas were visited, and geological development and production problems were discussed with the technologists of the various companies operating in these areas, particular attention being paid to problems relating to deep drilling and to methods of increasing recovery from partially depleted fields.

From Oklahoma to Wyoming, a detour was made to visit the United States Experimental Oil Shale plant at Rifle, Colorado, where the occurrence of oil shale in the Green River formation and the methods of retorting this shale were studied. Samples of the various grades of oil shale were also collected and despatched to Calcutta to be placed in the mineral collection of the Survey.

In October Mr. Barber attended the meetings of the Petroleum Division of the American Institute of Mining and Metallurgical Engineers and the International Petroleum Exposition held at Tulsa, Oklahoma. Advantage was taken of the opportunity these technical sessions afforded to discuss various development and production problems with representatives from all parts of the United States and many foreign producing countries.

A confidential report on the results of this study leave in the United States of America was submitted in January 1929 and a paper dealing with rotary practice and factors affecting the recovery of oil from sands, has been prepared for publication in the Records.

In February 1929 Mr. Barber visited the oil mines at Pechelbronn, Alsace, in order to study the extraction of oil by underground mining. This method of extraction of oil from depleted sands, devised during the stress of the European War[1] to supply the German armies with the all-important petroleum products of which external supplies had been cut off by the allied blockade, has since proved commercially remunerative and at the present time is regarded by many competent observers as the best method of obtaining the greatest percentage recovery from oil pools. M. Paul de Chambrier, Dr. Schnüders and the other technologists responsible for the development of this method at Pechelbronn, estimate that by underground mining an additional percentage of the oil-content of the sand equal to that obtained by boring operations is recoverable. This balance will almost certainly be disturbed by improved recovery methods such as repressuring, and possibly flooding and vacuum, applied to drilled properties, but the most sanguine estimates of the recovery obtainable by these methods do not exceed 66 per cent. of the total oil-content of the reservoirs. It may be anticipated therefore, that in the near future underground mining, possibly combined with some system of forced drive, will be resorted to in many areas for the purpose of extracting the large residues of oil which cannot be recovered by operations conducted from the surface.

Mr. Barber resumed the duties of Resident Geologist, Yenangyaung, Burma, on March the 10th, 1929. In addition to routine advisory duties in connection with every producing field in Burma a detailed investigation of the Yenangyaung field was commenced. An analysis is being made of the histories of the 3,000 odd wells situated in this field. This is a long and laborious process and so far has been completed only for Water-areas A, C, D, F and I in the Twingon reserve.

It has also been found that for a proper understanding of the distribution of oil and water in the deeper sands of the field a knowledge of the asymmetry of the structure is essential. At ordinary

[1] Underground mining was actually commenced at Pechelbronn as early as 1735 and was carried on without interruption till 1888, when working became dangerous and costly and was abandoned. It was not revived till 1915.

depths such as were penetrated in 1910 when Sir Edwin Pascoe prepared his Memoir on the Oil Fields of Burma, the effects of the asymmetry of this structure were so slight as to escape detection, but with the progressive penetration of deeper horizons its effects become increasingly apparent. This feature of the Yenangyaung structure was first recognised by the geological staff of the Burmah Oil Company. With a view to determining as far as possible the hade of the axial plane, a resurvey of the field on the excellent 24-inch topographical maps, available through the courtesy of the Burmah Oil Company, has been undertaken. Among other interesting results of this work may be mentioned the discovery of a fossil leaf-bed in the Irrawadian approximately 100 feet above the Red Bed in Outer Beme and of a land vertebrate tooth in the Pegu series 500 feet below the Red Bed in east Khodaung. The latter was forwarded to Calcutta for identification.

In connection with the isolation policy in East Twingon, the water conditions in wells situated in Water-areas C, F and I of the Twingon reserve were investigated in order to ascertain the effects of combining the 3rd and 4th isolations in these areas on the water production of neighbouring wells. The original isolation policy in this area called for isolations at approximately 1,000, 1,400, 1,900, and 2,400 feet. In certain wells in this area the normal 3rd isolation at 1,900 feet has been omitted and back-cementation from 2,400 feet has been attempted for the protection of the intermediate sands. There appears to be no evidence that the production of neighbouring wells producing from the intermediate sands has been affected by this procedure, but the data available from the comparatively limited application of this policy in these areas is inadequate at the present time to form the basis of any broad generalisation as to the merits of this casing policy.

A survey of abandoned wells in the various fields in Burma has been made with a view to standardising and in some instances improving the method of plugging wells in the future. The procedure for plugging wells in the reserves of the Yenangyaung field is also under discussion.

Jubbulpore District, Central Provinces.

Six weeks were spent by Mr. Crookshank in visiting the various Gondwana exposures between Jubbulpore and the Sher river, and in surveying certain unmapped crystalline areas lying in this region.

The Gondwana rocks occur as a series of isolated outcrops at the base of the Lameta or trap formations. They are characterized by the presence of white clays, and of numerous ill-preserved plant remains. These features suggest that they are all outliers of the main Jabalpur formation.

The crystallines consist of dolomitic limestones, slates, quartzites, granitic gneiss, and hornblende-schist. These rocks have been only moderately metamorphosed, as is shown by the absence of garnets and other minerals usually associated with high temperatures and pressures.

The quartzites appear to have been derived from limestones by replacement of lime by silica. The presence in them of much chalcedony, and of numerous open cavities suggests that the replacement is due to the action of meteoric waters. Mr. Crookshank considers it probable that the original limestones have been altered to quartzites wherever they have been broken up, by folds or faults. The age of this remarkable replacement is uncertain, but there is some reason to suppose that it is post-Gondwana.

Thin bands of hornblende-schist occur in numerous places in the limestone, and in the granitic gneiss. Their origin probably varies in different areas, but in some cases they have been formed by the alteration of ancient porphyrite intrusions, as is proved by the occurrence of almost unaltered porphyrite passing into hornblende-schist on the Sher river. A further metamorphosis from hornblende-schist to impure soapstone may also be seen in the same locality. A few small veins of chrysotile were noted in the limestone along the edge of the plain near Bachai (22° 52′ ; 79° 19′). These are of no commercial value, but are of some interest as they show that that mineral is sometimes formed in these limestones.

The remainder of the field season was spent by Mr. Crookshank in the low ground surrounding the Mahadeva hills. The area north of this range was mapped between the Tawa river and the Piparia-Pachmarhi road. Traverses were also made from the cliffs which form the southern boundary of the Pachmarhi *massif* to the Tamia-Gof ridge. The rocks seen belong to the crystalline and Gondwana systems, to the Lameta group, and to the Deccan Trap series.

The crystallines occur in a few narrow outcrops along the edge of the Narbada plain towards the north-western end of the region mapped. They consist mainly of limestones and slates similar to

those seen further east. Their junction with all the other rocks of the area is markedly uncomformable, and may also be faulted, though there is no definite evidence to that effect.

Representatives of all the Gondwana stages found in the Satpura region probably occur in the low ground on either side of the Pachmarhi plateau. In consultation with Drs. Cotter and Fox the following provisional classification has been arrived at and it is hoped to confirm this in the coming field season :—

Series.	Group.	Stage.	Old position in Indian stratigraphy.	New position in Indian stratigraphy.	World Scale.
Upper Gondwanas.	Umia & Jabalpur.	Umia . .	Jabalpur . .	..	L. Cretaceous to Portlandian.
	Rajmahal & Mahadeva.	Kota . .	Bagra . .	Jabalpur . .	L. Oolite.
		Rajmahal .	Denwa . .	..	Lias.
			Pachmarhi (?) .	Denwa & Motur	Rhætic to U. Trias.
Lower Gondwanas.	Panchet .	Panchet .	Almod ? . .	Pachmarhi .	L. Trias.
		Raniganj .	Bijori . .	Bijori . .	U. Permian.
	Damuda .	Ironstone shales. .	Motur . .	..	..
			..	..	..
		Barakar .	Barakar . .		L. Permian.
		Karharbari .	Karharbari .	..	..
	Talchir .	Talchir .	Talchir . .		..

The Talchirs are confined to the edge of the Narbada valley, where they cover a large area lying between the Pachmarhi-Piparia road and Hathnikhapa. They consist of the usual green clays in which erratic boulders are often seen. A study of the latter suggests that the ice which evidently deposited these sediments came from the northern side of the valley. These rocks, which are probably some hundreds of feet thick, have been much folded, and are faulted against trap flows to the north, and Denwa clays to the south.

Barakars have not been identified by Mr. Crookshank with any certainty, but a small patch of massive sandstone abutting on the Talchirs near Anhoni is believed to represent this stage.

Bijori rocks extend from the 2,500-foot contour on the scarp south of Pachmarhi to the base of the Deccan trap on the Motur-Tamia plateau. A small outcrop of carbonaceous rocks on the

Tawa river ⅓ mile south of Ranipura (22° 34′ ; 77° 59′) is also doubtfully attributed to this group. The appearance of the Bijoris varies greatly from place to place, but they are characteristically earthy, carbonaceous, and micaceous. *Glossopteris* remains are abundant, but no other fossils were found by Mr. Crookshank. As the base of this stage is nowhere exposed, its thickness is uncertain, but cannot be less than 1,000 feet. The Bijori rocks have suffered some folding and faulting, but the dips observed rarely exceed 20°. On their northern border they appear to pass comformably beneath the Pachmarhi sandstones, and on their southern they underlie, with marked discordance, the Denwas, Lametas, and Deccan trap.

Rocks of the Pachmarhi stage occur in the Mahadeva range, in the lower Tawa valley, and in the plain about Magaria (22° 36′, 78° 6′). This formation is built up of massive sandstone beds separated from one another by thin bands of conglomerate. In most sections it appears to dip north beneath the Denwa rocks, but in the Tawa valley it is divided from them by a marked unconformity. The existence of this break is Mr. Crookshank's reason for classifying this stage as the uppermost of the Lower Gondwanas. The thickness of these rocks is about 2,000 feet, and their degree of disturbance is similar to that of the Bijoris.

On the denuded surfaces of all the older rocks lies a sedimentary series composed of conglomerates, sandstones, nodular limestones, and highly coloured clays. This has been described as Denwa or Bagra, depending on whether the local facies is conglomeratic or clayey, respectively. There seems to be no need of two names, and as the clayey facies is the more characteristic one, it is proposed to drop the name Bagra as a stage term in favour of Denwa. These rocks are sharply folded along the edge of the Narbada valley, but become less and less disturbed as they are followed to the south, so that they are nearly horizontal in the cliffs east of Tamia. Definite evidence of faulting was only found in the Tawa valley, where the Denwas and Pachmarhis abut, but there is reason to suppose that faults are common especially in the vicinity of the numerous dykes which cut this formation. In a section near Thana (22° 38′ ; 78° 9′), where the clayey facies predominates, 1,700 feet of these rocks are present. In conglomeratic areas their thickness would probably be much greater. Although the Denwa rocks are divided from the Moturs by a wide strip of basalt, they

are, according to descriptions, exactly similar in appearance, and are almost certainly identical.

Outliers of the Jabalpur formation were found by Mr. Crookshank between Parsapani (22° 35′; 78° 3′) and Bagra, and in the Dundadehi reserved forest near Thana. They were characterized by the usual fine sandstones, white clays, lenticles of nodular hæmatite, and coaly beds. For rocks of this stage they were exceptionally folded, and cases occur near Thana where they dip north up to 70°. Plant remains were found in numerous places north of Parsapani in a fair state of preservation. Along with the commoner Jabalpur species were found the following plants which had till recently only been recorded from the Rajmahal or Kota rocks:—

Dictyozamites indicus,

Tæniopteris crassinervis,

Tæniopteris spathulata,

Nilssonia princeps.

As the result of recent discoveries of Rajmahal species in the Jabalpur rocks, Dr. Cotter is of the opinion that the Jabalpur should be classed with the Kota, a stage which is also distinguished by a flora mid-way between the Rajmahal and Umia.

The present rectilinear boundaries of the Narbada valley are in many cases the result of faulting, most of which evidently took place towards the close of the Deccan Trap era. The faults form a parallel series with a general downthrow towards the north, and an E.-W. direction. They do not as a rule correspond to the scarp formed by the Gondwana rocks, though they probably did so before denudation weathered this back. Most of them occur in the ground along the edge of the plain where they cannot readily be detected owing to the alluvial covering, but the presence of trap flows in many places along the edge of the plain is regarded as proof of their existence.

Assuming that Gondwana rocks do in some places underlie the alluvium, there is no reason why they should not in some cases contain coal measures. The presence of trap flows at the edge of the alluvium proves that the whole valley has been let down several thousand feet. It is unlikely, therefore, that coal measures exist within reasonable distance of the surface. If they are anywhere present at a reasonable depth, Mr. Crookshank observes that

they will probably be found in the faulted sides of the valley, as is the case at Mohpani and, as in the latter place, will probably be found to be badly crushed and faulted.

Along the scarp between Tamia and Gof Terai a thin band of calcareous conglomerates separates the Gondwanas from the overlying trap. This is thought to be a local variation of the usual Lameta formation. Fossil wood, some of which is palmaceous, was found on the surface of this conglomerate in two places.

As the result of detailed mapping around Jubbulpore Dr. C. A. Matley came to the conclusion that there was no break between the Jabalpurs and the Lametas. He showed that the evidence on this point depended to some extent on the comparison of the Jabalpur flora and the Lameta fauna. As these are not strictly comparable he considered that the evidence required revision. The occurrence of fossil palms in the Lametas makes a juster comparison possible. No palm trees have yet been found in any of the Gondwana rocks; their presence in the Lametas consequently indicates a big step forward in the evolution of plant life in the Indian region. The old view of a marked unconformity or non-sequence between the Gondwanas and the Lametas is, therefore, probably the correct one. The only change in our knowledge of these two formations is that Mr. Crookshank's discoveries of a Rajmahal (Kota) flora in the Jabalpur beds have tended to widen, rather than to bridge, the gap between the Lametas and the Jabalpur stage.

The most interesting observations made on the **Deccan Trap** rocks were the occurrence of trap flows along the southern border of the Narbada valley, and the presence of a composite dyke 1 mile S. S. W. of Sukhdongar (22° 24′; 78° 29′). The significance of the former has already been considered in connection with the northern boundary of the Satpura Gondwana basin. The evidence on which the basalts there seen were considered to be flows was not however given. The main points in this evidence are the wide area covered by these rocks, and their uniformly fine-grained texture. These two points taken together are, in Mr. Crookshank's opinion, proofs of their extrusive nature. The Sukhdongar dyke is built up of three portions 7, 10 and 17 yards wide as one crosses the intrusion from north to south. The central portion is a white fine-grained

granitic rock having a specific gravity of 2·7, and composed of quartz, oligoclase, perthite, chlorophæite, biotite, iron ore, and apatite. Its microscopic texture closely resembles that of a coarse-grained Deccan Trap flow. The south side of the dyke is a very coarse olivine dolerite, and the north side a medium-grained dolerite without olivine. There is little evidence as to the age of the various components of this dyke, but the centre is thought to be the most recent part of it. It can be followed through the rocks of the Bijori stage for at least a mile, and probably extends much further.

Bhandara District, Central Provinces.

Dr. S. K. Chatterjee completed the survey of sheet 55 O/16 (Sakoli sheet), of which the survey was commenced in the previous field-season. In this sheet much of the ground is obscured by alluvium, through which the underlying rocks protrude at intervals. In the north-eastern portion of the sheet, however, there is a hilly tract occupied by the Gaikhuri range; the rocks here are much folded, and the sequence is consequently difficult to determine. Dr. Chatterjee considers that the upper portion of the sequence may be arranged in the following descending order:—

Sheared and crushed microcline-albite-quartzite, perhaps of igneous origin;

Buff, siliceous, slaty shale;

Phyllite;

Sericite-quartzite and carbonaceous haematite-quartzite, both occasionally somewhat chloritic, and passing into each other laterally;

Phyllite, often chloritoid-bearing and garnet-bearing, and ferruginous chert;

Chloritoid-bearing chlorite-muscovite-schists with porphyroblasts of chlorite or garnet and rarely staurolite and chiastolite.

In the southern part of the sheet, the relationships of the rocks to one another are much obscured by alluvium. Rutile-quartz-tourmaline-schists, containing a considerable amount of kyanite, dumortierite or sillimanite, are found, and are regarded by Dr. Chatterjee as having been developed from the chlorite-muscovite-schists as the result of pneumatolytic and hydrothermal meta-

morphism due to a later granitic magma. As, however, there are no exposures of such a magma, though quartz veins are numerous, his conclusion must be regarded as requiring the support of further evidence before it can be accepted. The alternative hypothesis is that of Dr. Dunn, who has described the sillimanitic rocks of Pohra.[1] Dr. Dunn's suggestion is that these highly aluminous rocks do not owe their formation to the alteration of once less aluminous schists, but represent original bauxitic or other highly aluminous clays occurring interstratified in the succession of sediments from which the series of schists has been derived.

In addition to the phyllites and schists enumerated above, Dr. Chatterjee has found amphibolites, and, in one place, namely, at Dhimarwara in the north-west corner of the sheet, dolomitic marbles, which he regards as underlying the phyllites and schists. Adopting the view that these amphibolites and marbles correspond respectively with the Sitapar and Bichua stages of the succession recognised in the Sausar *tahsil* (the Sausar series), Dr. Chatterjee attempts to correlate the overlying phyllites, schists, and ferruginous and other quartzites with the Sapghota and Ramtek stages of the Sausar series. The grade of metamorphism, however, of the rocks assigned to these two stages on Dr. Chatterjee's sheet is, according to Dr. Fermor, lower than that in the Sausar area. Dr. Chatterjee's view is different from that of Mr. Bhattacharji, who, working on the Bhandara sheet to the west, regards these same phyllites, schists, and quartzites as representing a succession lying conformably above the Sausar series. This is one of the points that it is hoped ultimately to determine as a result of the present survey.

In the Gaikhuri range, north-east of Kohka (21° 12′; 79° 47′), Dr. Chatterjee has mapped a thrust-fault separating sheared hæmatitic grits from phyllites. Within the phyllites are occurrences of sheared felspathic quartzite, which have been converted into autoclastic conglomerates, the strike of the axes of the pseudo-pebbles making a sharp angle with the general strike of the bands of rock. With reference to the general metamorphism of this tract, Dr. Chatterjee produces evidence of more than one period of diastrophism. The following analysis is given of a specimen from 1 mile

[1] *Mem. Geol. Surv. Ind.*, LII, p. 204 (1929).

north of Nawegaon (21° 12′; 79° 53′) of chlorite-muscovite-schist, carrying staurolite, chiastolite and chloritoid:—

	Per cent.
SiO_2	54·99
TiO_2	0·22
Al_2O_3	20·30
Cr_2O_3	*Nil*
Fe_2O_3	8·03
FeO	4·40
MnO	0·24
MgO	2·83
CaO	0·26
BaO	trace
Na_2O	1·23
K_2O+	3·02
H_2O (>110°C)	3·54
P_2O_5	0·18
S	0·03
C	0·15
H_2O (<110°C)	0·14
CO_2	0·04
	100·24
	Sp. gr. 2·83.

This analysis appears to afford evidence that the schist in question is of sedimentary origin.

During the field season, Sub-Assistant D. S. Bhattacharji completed the survey of the Bhandara sheet (55 O/12). In the previous report it was mentioned that the boundary between the more metamorphosed type of country in which the Sausar series occurs, and the less metamorphosed country referred to as the Bhandara belt of Dharwars, traverses this sheet in a east-north-easterly direction. When Mr. Bhattacharji came to complete the south-western corner of the Bhandara sheet, he found there occurrences of rocks of the Sausar type, such as quartzites of the Ramtek stage, amphibolites of the Sitapar stage, calc-magnesium-granulites of the Bichua stage, and marbles and calc-granulites of the Lohangi and Utikata stages, respectively, of the Sausar series. As these occurrences, which are associated with gneisses of the type characteristic of the Sausar belt, occur on the strike of the rocks of the less metamorphosed Bhandara type, it appears that the boundary between the two types of rocks is becoming more complex to the south-west, and for this reason Mr. Bhattacharji, after completing the Bhandara sheet,

commenced work on the Umrer sheet, No. 55 P/5, lying to the south-west, surveying the north-eastern corner thereof. The discovery near Viakhandi (20° 55′; 79° 25′) of a small outcrop of gonditic rock is interesting, as this is the only such occurrence found to the south of the main line of the Bengal-Nagpur railway. It is hoped that further work on this sheet may help in the unravelling of the relationship between these two types of Archæan rocks. Work has not yet progressed far enough on this sheet to permit of further discussion this year, except to record that Mr. Bhattacharji has been unable anywhere to find any unconformity between the Sausar and Bhandara belts of rock; it seems likely, therefore, that the relationship between the two groups is a conformable one, and that the Bhandara type of schists may be an upward continuation of the succession to which the name Sausar series has been applied. Mr. Bhattacharji's report is, as usual, illustrated with suitable photographs and well-drawn sketches. Accounts are given of the mineralogy of the various types of schists recognised. One point of interest is that in the chloritic sericite-quartz-schists Mr. Bhattacharji has recognised dumortierite, the discovery of which by Dr. Chatterjee on the adjoining sheet to the east has already been recorded. The presence of this boron-bearing mineral and the abundant tourmaline seen, for instance, in the kyanite-quartz-tourmaline-schists of this tract support the view that there may have been later pneumatolytic additions to the phyllites and schists of the Bhandara type. The difficulty is that actual occurrences of acid granitic rocks intrusive into these schists and phyllites are scarce. Mr. Bhattacharji regards the porphyritic granite of Jamgaon (21° 1′; 79° 38′) as responsible for the tourmalinisation of adjoining schists of the Bhandara belt.

Coal-fields Party.

Although the geological surveys of the Jharia and Raniganj coalfields were practically completed in the previous season (1927-28), there remained a few details which required attention. Dr. C. S. Fox remained in charge of the Coalfields party, and was assisted by the late Mr. Sethu Rama Rau and Mr. E. R. Gee. Mr. Sethu Rama Rau's work included a search for fossils in the area E. N. E. of the Raniganj coalfield and in the supra-Panchet or Dubrajpur beds capping Panchet hill. Mr. Gee made an examination of those parts of the Raniganj field with which he was still unfamiliar, and he will now be in a position to complete his memoir on the Raniganj coalfield, which,

it is hoped, will be published before the end of 1930. The new geological maps—21 sheets on a scale of 4 inches to the mile—of the Raniganj coalfield are in process of publication, and it is hoped that they will be issued during the first half of 1930.

Dr. Fox's memoir on the geology and coal reserves of the Jharia coalfield is in the press, and should be ready for issue early in 1930. The author has found it necessary to modify the old grouping of the Damuda beds in the Jharia coalfield, and in consultation with Mr. Gee has correlated the various stages with those of Raniganj. The following tables shew the classification and relationship adopted:

Sub-divisions in the Jharia Coalfield.		Dr. W. T. Blanford's divisions in the Raniganj coalfield.
Raniganj series 1,840 ft.	Lohpiti sandstones Telmucha coal-measures Jamdiha sandstones Murulidih coal-measures	Raniganj series, 5,000 ft.
Barren measures, 2,080 ft.	Mahuda sandstones Hariharpur carbonaceous shales Petia sandstones Shibbabudih carbonaceous shales	Ironstone Shales. 1,400 ft.
Barakar series, 2,000 ft.	Bhagaband coal seams Jialgara coal seams Gareira coal seams Muraidih coal seams	Barakar series, 2,000 ft.

Dr. Fox's subdivisions in the Jharia Coalfield.		Mr. E. R. Gee's subdivisions in the Raniganj Coalfield.	
	Lohpiti sandstones Telmucha coal-measures Jamdiha sandstones Murilidih coal-measures	Kumarpur sandstones Nituria coal-measures Hijuli sandstones Sitarampur coal measures.	Raniganj series, 3,300 ft.
Barren measures, 2,080 ft.	Mahuda sandstones Hariharpur carbonaceous shales.	Ethora sandstones Kulti Ironstone shales	Ironstone Shales, 1,200 ft.
	Petia sandstones Shibbabudih carbonaceous shales.	Begunia sandstones Begunia carbonaceous shales.	Barakar series, 2,100 ft.
Barakar series, 2,000 ft.	Bhagaband seams Jialgara seams Gareira seams Muraidih seams	Begunia seams Laikdih seams Ramnagar seams Damagaria seams	

In view of the above correlation, it becomes quite certain that the Damuda group originally spread continuously from the Jharia field into Raniganj. It is also Dr. Fox's opinion that these rocks extended without a break up the Damuda valley. The Jharia sub-

divisions have not been introduced into the nomenclature of the Raniganj coalfield for two reasons. The first is that Dr. Blanford's divisions are now too well known, and any serious change would introduce confusion. The second is that the correlation was established after the surveys were completed and the detailed divisions have not been separately mapped in the Raniganj coalfield. It will be noticed, however, that Dr. Blanford's Ironstone shales have been slightly curtailed by Mr. Gee. This was found necessary after the Begunia sandstones were proved to be not unconformable on the Barakars (*Rec. Geol. Surv. Ind.*, Vol. LX, pp. 363-364). It should also be noted that the Raniganj series is thicker and far more important as a coal-bearing formation in the Raniganj area than it is in the Jharia coalfield. The reverse is in general true of the Barakar series of Jharia when compared with the same formation in the eastern part of the Raniganj coalfield.

Burma coal fields.

After completing his surveys in the Jharia and Raniganj coalfields Dr. Fox visited the more important coalfields in Burma—the Jurassic coal measures in the Southern Shan States around Kalaw, the Pleistocene lignitic coals of Nam-ma and Lashio in the Northern Shan States, and the Eocene coals of the Kalewa area in the Upper Chindwin valley. There are several outliers of the Jurassic coal measures in the Southern Shan States and in the Meiktila district. The best-known of these is the Loi-an coalfield near Kalaw. Dr. Fox considers that the Jurassic outlier near Loi-an, with rocks ranging from Lias to Lower Oolite, is of too limited an extent and too disturbed as to its seams to be of any serious economic value, although samples of the coal are of attractive quality and show caking properties.

Dr. Fox found freshwater gastropod shells in both the Lashio and Nam-ma fields, but this fauna was not sufficient to settle definitely whether the shales are of Pliocene or Pleistocene age. Although some considerable distance from the railway, Nam-ma is thought to be the more attractive field. It is true that the high moisture content of the fuel, as first mined, gives it a low calorific value, but when dried, this black, lustrous lignitic coal is not unattractive as a steam-raising fuel. Owing to decrepitation, the coal would not stand transport to any distance, but the Nam-ma coalfield may prove of considerable value if electric power is generated there and transmitted to Namtu and the Bawdwin mines. The hydro-electric capacity of the river will not meet the requirements of the

mines and smelters, and auxiliary Diesel oil engines have already been installed. The supply of power from Nam-ma is therefore worthy of serious attention.

Although the Kalewa coalfield is also situated in a remote locality and the tests with the coal from the outcrop have been disappointing, the field has possibilities. From surface evidence there appears to be a fairly large tract of coal-bearing strata. There is one seam of 8 feet, and two others measure from 3 to 4 feet. Unfortunately, it is a high-moisture coal and of poor heating value, although the ash content is low. Dr. Fox thinks it may be found to contain less moisture further to the dip, but, to prove this, borings would have to be put down; such borings would be highly speculative. A collection of gastropods at Kalewa from an horizon just above the 8-foot seam appears to consist entirely of two species of *Melania*—brackish water forms thought to indicate a Yaw stage horizon.

Raniganj Coal-field, Bihar.

During the first half of the field-season 1928-29, Mr. E. R. Gee concluded the re-survey of the Raniganj coalfield, and the areas examined included Sheets 1 to 4, west of the Barakar river, and Sheets 5, 6, 9 and 10, south of the Damodar river. In addition, a brief visit was paid to the extreme eastern end of the coalfield, Sheets 22 to 24. As a result of this examination Mr. Gee has been able to arrive at a fair correlation of the principal coal seams of the field.

Within Sheets 1 to 4 the Talchir strata, dipping in general to the S. or S.S.W., rest on the metamorphics, and are overlain to the south by the Barakar series. The latter covers the greater part of Sheets 1, 2 and 4, the structure of the lower beds, at least to the west of the longitude of Kumhardubhi, being very simple, with steady dips to the S.S.W. Approaching the main boundary fault of the coalfield to the south, the outcrops of the middle and upper Barakar beds are naturally more complicated. In addition to a main synclinal structure along the line of the fault, stresses at right angles have caused the beds to crop out in the form of two small basins to the west, the Shampur and Chatabar basins, and as the Kudia syncline, complicated by faulting, in the eastern part of the area. The outcrops in the west are clear, particularly in the Kudia Nala section of Sheet 2, intersecting the strata of the Shampur basin. Within this basin, although no Ironstone shales are present, it seems probable that almost the whole of the upper Barakar is represented.

Within the Chatabar and Kudia areas, the upper Barakars are absent. These upper beds with coal-seams come in again near Chanch to the west of the Barakar river 4 miles from the eastern edge of the Shampur basin, so that in comparing the upper Barakar coal-seams of these two areas it is not surprising to find that certain changes have taken place. For the purpose of correlation the Rangamati Gopinathpur seam, with massive grits and fireclays associated above and below, forms a very useful horizon. The principal points of the correlation arrived at by Mr. Gee are summarised as follows.

The Pusai seam of Sheet 1 represents the basal coal-seam of the Barakar series. It occurs only a short distance above the uppermost Talchirs, and immediately beneath the thick pebble-bearing sandstones of the lower Barakars. This seam, 30 feet thick in Sheet 1, thins to the east, and is possibly represented by the thin Farewell seam of the middle portion of the field.

Several coal-seams crop out to the south of the Pusai in Sheet 1, but appear to be of no present economic importance. In the north-western part of Sheet 4, one of these seams becomes of individual value and thickens to the east to form the thick Kalimati seam; it is represented in the wide outcrops of coked coal (*jhamma*) and mica-peridotite in the Barmundih area, and from its general character and its position above the pebble-bearing sandstones, is correlated with the thick Damagaria seam to the east.

Higher in the succession, a seam of shaly coal crops out in the northwestern part of Sheet 4, and continues to the east as the Bindabanpur seam. Several coal-seams appear to occur about this horizon in the area east of Kumhardubhi, and are proved in the borings of Ramnagar to the east.

Thick massive grits with fireclays follow, and include the Rangamati-Gopinathpur seam, 12-14 feet thick. Within the complicated area east of Kumhardubhi, this seam is possibly repeated by faulting. It is correlated with the Bahira '5,' the equivalent of the Salanpur 'C' seam of Sheet 8.

Following these upper grits are shales, including a thin coal and fireclay seam, the Kudia shale group of Mr. Auden. These beds are succeeded by the thick seams of the middle Barakars, represented by the Shampur, '5' & '6' seams, the thick Chatabar seam, the 45-foot Patlabari seam, and the Laikdih seam. It is possible

that the Ramnagar seam of the east is represented by the upper portion of the thick Laikdih seam of the Kumhardubhi area.

Within the Shampur area several seams of shale and coal occur within the 450-500 feet of strata above No. 5 seam. It is suggested that in the outcrops of the upper Barakar beds of the southeast of Sheet 4 these coal and shale beds are represented by the thick carbonaceous shales of the equivalent succession. At the top of this series in the Shampur basin is a 10-foot seam of good quality, the Top Fotka seam. This is correlated with the Chanch-Begunia seam of the east.

About 200 feet above this 10-foot seam is a thin seam, both in the Shampur and the Chanch areas.

The thickness of the Barakars of the western part of the field, is very similar to that of the eastern, and approximates 2,100 feet.

Within Sheets 5 and 6, to the west of Luhchibad, the uppermost Barakars, including the Begunia seam, abut against the metamorphics of the main boundary fault. This fault here follows a southeasterly direction, and appears to continue as a cross-fault to the west of Raghunathpur, bringing in the Talchirs of the west against the Ironstone shales to the east. Mr. Gee remarks that it may well be the continuation of this displacement which continues through the Deoli-Nadiha area and, showing a hade to the northeast of 45°—50°, displaces the Raniganj beds, including the Dishergarh seam, to the extent of 500 feet. To the west of this fault, just north of the Damodar river, the Talchirs are well-exposed resting on the metamorphics. They are, here, very thin, though the boundary appears to be a natural one of deposition; the Barakars, with a basal pebble-bed, crop out a short distance above. On the south side of the Damodar these Barakars appear to rest directly on the metamorphics, and after a relatively small thickness of massive grits, sandstones, and shales with thin coal-seam outcrops, all dipping steeply to the E.S.E., these typical Barakar types pass up into shales with ironstones. The upper Barakar sandstones pass laterally into grey shales and sandy shales with ironstone bands, so that the Barakar-Ironstone shale junction is less distinct than in the areas to the north. Above a relatively thin Ironstone Shale group, typical Raniganj beds crop out covering a large part of Sheets 5 and 6. Of the seams of these lower measures of the Raniganj group, the Dishergarh seam is alone worked at the present time, at the collieries of Saltore, Deoli, Nadiha, and Parbelia. It is from

15-16 feet thick to the northeast but thins somewhat and deteriorates in quality to the southwest. Several thin seams of inferior quality crop out in the upper measures and, like the Sanctoria seam below the Dishergarh, have been worked in the past. Generally speaking, the upper Raniganj beds, with Panchets above them, form a syncline pitching eastwards in the eastern part of Sheets 5 and 9. The southern limb of this syncline in Sheet 6 is faulted, and the beds turn over to the southern boundary-fault as the southern edge of the coalfield is approached. Near this boundary-fault the Panchets, with Dubrajpur beds (supra-Panchets) above, forming the Panchet, Gorangi, and Beharinath hills, overlie these Raniganj beds. Within the lower Panchet beds of Sheet 10, fish-scales and doubtful *Estheria* remains were discovered, together with a few imperfect plant impressions. Near the line of the main boundary-fault in Sheet 14, the uppermost Raniganj beds, with well-preserved fossil leaves, crop out in several small inliers.

The grits and sandstones of the Durgapur area of the eastern part of the field, were examined by Mr. Gee. These beds include bands of red and whitish clays, and are pebbly in some exposures. They bear a certain resemblance to the Dubrajpur beds of the western part of the field, and in the absence of fossil evidence have been tentatively correlated with these strata. The middle Panchet beds, which crop out near Andal appear to overlap on to the upper Raniganj rocks, and there is some evidence to suggest that, further east, the Durgapur beds also overlap on to these upper Raniganj horizons.

Large areas of laterite, varying to a lateritic conglomerate and a semi-consolidated quartzite gravel-bed to the east, cover wide tracts in the eastern part of the coalfield. The laterite appeared to Mr. Gee to have been derived from a ferruginous sandstone bed deposited in sub-Recent times. In the eastern part of the field the Raniganj and Durgapur beds are often overlain unconformably by a coarse gravel-bed consisting almost entirely of well-rounded quartzite pebbles in a yellow to red ferruginous matrix. This pebble-bed passes up into a ferruginous grit with fewer pebbles, the upper 4 to 5 feet being converted into laterite. This laterite zone includes an upper portion of hard boulder laterite, and a lower section of rubbly laterite. To the west, the basal gravel bed is not represented; from 2-5 feet of laterite, rubbly and gritty below, rest somewhat irregularly on the Raniganj sandstones.

At a more recent date this laterite land-surface was intersected by erosion and in the lower ground thick deposits of a clayey alluvium were laid down. This alluvium covers large areas of the south-eastern part of the coal-field so that the laterite-covered tract is now exposed as islands in the alluvial sea.

Mysore.

At the beginning of the field season a visit was paid by Rao Bahadur Vinayak Rao to the Sakarsanhalli area where manganiferous limestones are found. These occur in the Mysore State bordering the Kangundi zemindari in the Chittoor district and are almost 4 miles from Bisanattam railway station on the Madras and Southern Mahratta Railway. The area consists of garnetiferous gneisses, pegmatites, and aplites which have intruded into diopsidites, micaceous schists, and hæmatitic quartzites which form a thin band and must be referred to the Dharwars. The manganiferous limestone which is found only near the village Sakarsanhalli is of secondary origin and is derived from the manganese garnet. It has been worked out.

N. Arcot District, Madras.

Sheets 57 P/5 and 57 P/1 were mapped by Mr. Vinayak Rao in detail. An interesting occurrence of dunite was discovered in the hills 4 miles east of Vellore town. The dunite forms a low hill extending in a north-eastern direction and is associated with the norites of the charnockite series.

The following rock formations were noticed:—

Older gneisses and schists.
Charnockites.
Augite-syenite.
Garnetiferous gneiss.
Gingee gneiss.
Hornblendic gneiss.

Though no mention is made of the Dharwars some ferruginous quartzites found in the charnockites and containing iron pyrites may perhaps be referred to this system. Further south bands of ferruginous quartzites and hornblende-schists have been noticed. Though the granites and gneisses have an intrusive relationship to them Mr. Vinayak Rao suggests that some of the contorted mica-schists and gneisses found on the western edge of the Dharwar belt near Bisanattam railway station and near Jalarpet may be older than the Dharwars. Owing to subsequent intrusions the relationship between these older gneisses and the Dharwars cannot be made out with certainty. The charnockites are found as sills and form-

ing hill-masses similar to those in Kailasgarh about 4 miles S.W. of Vellore. They are mostly the intermediate and basic varieties. Associated with them are the garnetiferous leptynites, augite-syenites (near Jalarpet) and hornblendic gneisses. There seems to be a gradual passage from the intermediate and basic charnockites to the syenites and gneisses. The augite-syenites in which some of the augite crystals are found changing into hornblende, may be considered to be a little newer than the charnockites and of the same magmatic origin.

A number of E.-W. dykes are found in this area extending for several miles. They are mostly doleritic and in one place, south of Pusimalai Kuppam (57P/1. 79° 14′; 15° 46′) they seem to be intruded by a band of norite extending in a N.-S. direction.

A new type of rock containing hornblende and a pink felspar, generally coarse in texture, has been found forming the whole of the hill containing the famous fort of Gingee in the South Arcot district and it is proposed to call it the Gingee gneiss. Rocks of this type have been found as far west as Krishnagiri in the Salem district and near the sea-coast. They are also found extending north near Ranipet and other places.

The hornblendic gneiss, the Gingee gneiss, and the garnetiferous gneiss are probably all of the same age. These are the rocks which form the main masses of the hills in the North Arcot district. The garnetiferous gneiss is found extending for a considerable width in 57P/1 and forms hill-masses. In places the garnets are replaced by biotite and the biotite-gneiss found further north is concluded by Mr. Vinayak Rao to be of the same age as the garnetiferous gneiss. The charnockites form generally thin bands and sills in the eastern part of this area.

Potwar Plateau, Punjab.

Dr. G. de P. Cotter was again placed in charge of the Punjab Party, consisting of Messrs. D. N. Wadia and E. R. Gee, and Sub-Assistants H. M. Lahiri and P. N. Mukherjee, and commenced field work in the Pindi Gheb *tahsil* of the Attock district, where the mapping of the Potwar was continued from the area completed last year. Dr. Cotter, with the help of Mr. P. N. Mukherjee, who was placed under him for field training, was able to map the whole of sheet 43 C/8, and portions of sheets 43 C/3, 43 C/12, 43 D/5, and 38 O/15, which comprise parts of the Pindi Gheb and Talagang *tahsils* of the Attock district. The rocks of

the area mapped are entirely freshwater Tertiaries, ranging from the Murree series to the Upper Siwaliks.

Sheet 43 D/5, which was mapped mainly by Mr. P. N. Mukherjee, is covered entirely by Middle Siwaliks and alluvium. The Siwaliks dip gently north and form the southern flank of the Soan geo-syncline.

Dr. Cotter reports that Sheet 43 C/8, which lies to the north of D/5, shows a complete section from the Upper Siwaliks to the Kamlials. The northern part of this sheet contains the Dhulian dome, which was tested for oil some years ago by the Attock Oil Company. The anticlinal fold upon which the domes of Khaur and Dhulian are situated, continues right through the sheet from east to west. South of this fold is the great Soan geo-syncline, the northern flank of which extends to the middle of the sheet, while the south of the sheet shows almost horizontal beds which occupy an axial position in the geo-syncline. The Upper Siwaliks, exposed around Mathrala, are buff and brown sandstones and drab, brown and red clays. The basal beds on the north of the Upper Siwalik outcrop are conglomeratic, but no continuous bed of conglomerate was found on the southern margin, and the boundary had in consequence to be drawn by an approximate line. The Middle Siwaliks occupy most of the sheet and are rich in vertebrate remains south of Dhok Pathan. Several further specimens were obtained, but no new species added to the list given by Dr. Pilgrim in Records, volume XLIII, pp. 281-287.

The Dhulian fold shows an anticlinal crest which pitches both to the E.N.E. and the W.S.W. The anticline is continued westward by another crest disposed in echelon to that of Dhulian with a gentle syncline showing some contorted strata between the two crests. To test adequately the Dhulian dome for oil, would require a very deep test well. In view of the recent successful deep drilling at Khaur, Sheet 43 C/3 is, in Dr. Cotter's opinion, interesting, because of the various strike-faults which traverse it from east to west; these strike-faults, according to Dr. Cotter, mark the positions of crushed anticlinal crests. The rocks exposed in the sheet range from Murrees to Middle Siwaliks. In the southern portion of the sheet a crushed anticline in Chinjis occurs on which the village of Meyal-ki-dhok is situated; this area was tested by a deep bore many years ago by the Burmah Oil Co. The

sharpness of the anticlinal fold and the crushed crest made the prospects of oil doubtful, and the test was unsuccessful.

Hazara District, Punjab.

In the Hazara district, the northern portion of sheet 43 F/3 was mapped, special attention being paid to the rocks mapped by Mr. D. N. Wadia previously as doubtful Gondwanas in sheet 43 F/7 and those mapped under the same head last season in sheet 43 F/6.

The northern portion of sheet 43 F/3 presents the same features as the southern half, which was mapped about 30 years ago by Mr. C. S. Middlemiss, the results of whose survey were published in the Memoirs (Vol. XXVI). The rocks of the area are quartz-schists, mica-schists, and phyllites with granite intrusions. Both the granite and the schists are penetrated by dolerite dykes. An attempt was made to map separately the granite intrusions and the schists. Dr. Cotter agrees with the view expressed by Mr. C. S. Middlemiss that the schists are metamorphosed representatives of sedimentary rocks, mainly of the Hazara Slate series, but suggests that there may be other formations present as well, which cannot now be recognised or separated out owing to the metamorphism. Dr. Cotter examined the rocks near Garhi Habibullah Khan (sheet 43 F/7) which Mr. Wadia has referred tentatively to the Gondwanas. These rocks are also schists (quartz-mica-schists, mica-schists, and phyllites), and Dr. Cotter considers that, while more arenaceous as a whole than the Hazara slates, they cannot be separated with any certainty from the metamorphic schists generally of Hazara, nor from the schists in the north of 43 F/3. Some conglomerates and massive white quartzite east of Kagal village, 3 miles north of Garhi Habibullah Khan are probably of Infra-Trias age and are the metamorphic representatives of the Infra-Trias. If this correlation be correct, and if the Infra-Trias, as is supposed, be truly of Upper Carboniferous to Permian age, then this portion only of the schistose group would be of Gondwana age. The rest of the schists must, however, in Dr. Cotter's opinion, be regarded as older than the Infra-Trias, and possibly represent the Hazara slates and older formations It is possible also that in the schistose rocks, portions of the Devonian and Silurian are represented. It must be remembered, however, that in that part of Hazara mapped by Mr. C. S. Middlemiss the Infra-Trias rests directly on the Hazara slates of supposed Cambrian or pre-Cambrian age, and that the Lower Carboniferous, Devonian,

and Silurian are missing. Mr. Wadia has now modified his views and accepts in the main Dr. Cotter's conclusions.

Mr. D. N. Wadia spent the first part of the field season in mapping the Mt. Tilla, Bakrala, and Diljaba portion of the eastern Salt Range (Sheets 43 H/1 and H/5). The Mt. Tilla area was mapped on the 4-inch scale. A remarkable tectonic feature of this hill-mass is the overthrust of the Cambrian rocks, commencing with the Purple sandstone (which Mr. Wadia, following Wynne, has included with the Cambrian), exposed in the striking south-easterly escarpment, on to the Chinji stage of the Siwaliks, the plane of this thrust being observed as a winding line along the lower part of the escarpment for several miles. At the N.E. end, the Chinjis directly underlie the Neobolus shales, which are surmounted by the Magnesian sandstone (dolomite). Near milestone '20' of the Jhelum-Tilla road, between the Chinjis and the Neobolus beds, is a small patch of squeezed and rolled-in Eocene limestone, containing *Nummulites* and *Assilina*. No red Salt marl was observed on the Tilla scarp as a normal rock horizon, though small pockets of this rock, if crushed in with the bright red Chinji clays, would easily escape notice.

Eastern Salt Range, Punjab.

The northwestern face in which the exposures are much obscured by forest and scree, is a dip-slope of Magnesian sandstone, with a skin of Salt-pseudomorph shales, covered by patches of the Talchir boulder-bed and succeeded by 20-80 feet of Nummulitics, beginning with a pronounced basal lateritic bed. This is overlain by a complete sequence of the Upper Tertiaries. At two localities (Mahesian and Rakh Nili), elliptical dome-folds, encompassing considerable areas, were mapped by Mr. Wadia ; in the Mahesian dome the core-rock is Chinji, amid Middle Siwaliks with gentle qua-qua-versal dips while in the Rakh Nili faulted twin-dome fold, the arching of the axis of the Bakrala anticline has proceeded to such an extent as to reveal a central axial core of Lower Murrees. The crestal Murrees are surrounded on nearly three sides by an encircling escarpment of Kamlial sandstones on the unfaulted flank of the dome.

The northwestern limb of the Bakrala anticline is undisturbed, but its southeastern foot is considerably fractured by parallel strike-faults throwing down to the south, the throw of the fault increasing to the south-west, where typical Lower Murrees abut on vertical Middle Siwalik strata. Near Domeli, a faulted inlier of Nummulitics is exposed and at its base occur two or three strongly

saline springs slightly charged with sulphur; the source of the salt is probably a concealed outcrop of the Salt marl. Another salt-spring occurs in the Diljaba, 17 miles to the south-west, where the Nummulitic limestone reappears among steeply fractured and inverted Siwalik strata, followed 7 furlongs still further in this direction by the emergence of the Purple sandstone and later Cambrian rocks of the Diljaba. In spite of these salt springs, Mr. Wadia records the absence of any outcrop of the Salt marl beds in relation either to the Cambrian or the Eocene rocks of Diljaba.

In the mapping of the Diljaba hills, the chief difference from Wynne's map is the evidence obtained by Mr. Wadia of a *thrust* contact between the Cambrian rocks of its abrupt northwestern scarp and the Middle Siwalik forming the foot. Beds of the latter dip beneath the Purple sandstone and tongue out into the valleys a relationship observed along the whole northwestern face, from Ghora Gali to Shahpur, though the thick *sunnehta* scrub and debris have greatly obscured the sections. The existence of this thrust is corroborated by the presence of thin, short strips of Nummulitic limestone, cleanly wedged in among the succession mapped as Cambrian, a feature for which Mr. Wadia found it difficult to find any other explanation.

Resting between the steep, convergent dip-slopes of the Umrila plateau between the Tilla and Diljaba ridges, is a quadrilateral basin, the major synclinal depression of the area, produced by the fusion of two north-easterly pitching synclines. The whole Tertiary sequence, from the Eocene to the Tatrot zone, is represented except for the Chharat stage, which Mr. Wadia failed to recognise; the Murrees also are greatly reduced in thickness. The Murrees exhibit, save in the basal 100 feet or so, a modified facies of composition, resembling the Upper Murree stage of more northerly areas. Further westwards, towards Karangli, (Sheet 32 H/1) the Murree stage, according to Mr. Wadia, disappears altogether, by the thinning out of its basal part and the gradual lateral passage of its upper into the Kamlials, this stage attaining in this area a very full development (over 2,000 feet).

Mr. Wadia resumed the mapping of the Hazara-Kashmir syntaxis early in the spring. The main tectonic lines as well as the composition of the various post-Purana constituents of this belt of abnormal strike in the northwestern Himalaya have been studied up to Kaghan (Lat. N. 34° 47′). The inner boundary is described by Mr.

Hazara-Kashmir syntaxis.

Wadia as a thrustplane, along which Dogra slate and the oldest sedimentary rocks of the Himalaya—marble, calc-schists, and graphite-schists of the Salkhala series—have been slid bodily over the upper Carboniferous, by thrusts directed from the N.W. and N.E. Between these inner Purana slates and crystallines and the Oligocene Murree series, which constitutes the long central bay of the syntaxis, a well-defined linear zone of compressed, vertical strata stretches in a deep re-entrant loop into the inner mountains. The width of this zone is irregular, being determined by the varying amount of lateral movement that has taken place in the two bounding thrust-planes. Five distinct rock-systems were recognised between these two thrusts; these, in order from outside to inside, were: (1) Eocene, (2) Trias, (3) Carboniferous Panjal Volcanic series, (4) the Infra-Trias, and (5) the series of metamorphosed sediments, the Jured formation. The series of limestones usually known by the indefinite term 'Infra-Trias' have been found by Mr. Wadia to be interbedded and intimately associated with the Upper Carboniferous lava-flows and Agglomeratic slates, at several different localities, in a manner which suggests either contemporaneous deposition, or immediately subsequent injection of the lavas as sills. The altered arenaceous Jured sediments have been found to show an apparently conformable passage into the Agglomeratic slates. The latter have more of the character of volcanic tuff, even than they have in Kashmir. Some obscure *Fenestella*-like markings have been found in them.

Though a considerable amount of compression is visible in the vertically disposed bands of these strata, there is comparatively little contortion, shearing, or dynamic metamorphism. The inner of the two concurrent thrusts, between Manur and Balgiran, passes into a recumbent fracture, over which blocks of Salkhala schists have transgressed successive Palæozoic and Mesozoic belts and come to rest, near Machhiara and Galikhetar (sheet 43 F/11) on the Murrees. These Salkhala blocks have evidently travelled some distance from the east. The overthrust is described as one of progressive intensity from north to south, for, whereas the width of the various Carboniferous-Eocene belts is 5½ miles at the intersection of the Kunhar in the Malkand mountains, within a short distance it is reduced to ¼ mile, and at Galikhetar to almost nothing, in consequence of tongues of the older crystallines projecting out

towards the Murrees. On the western border the thrust is uniformly more intensive along the whole border.

In the synclinal trough of Palæozoic sediments in the Shamsh Abari range of the Karnah district of Kashmir (Sheet 43 F/15), rocks identified by Mr. Wadia as older Palæozoic last season have, at two or three localities, yielded fairly well preserved trilobites and Obolaceous brachiopods. The occurrence of fossils in this area is extremely sporadic and large expanses of rocks of absolutely identical composition and stratigraphic position have yielded nothing but some yellow blotches, streaks and dots on weathered surfaces. The trilobite genera, provisionally identified, are: *Conocoryphe, Agnostus,* and *Microdiscus* from one locality and some Acidaspid genera from another. The Cambrian-Silurian sequence is 7,000 feet thick; it is succeeded by 2,000 feet of Muth quartzites, 100 feet of Syringothyris limestone and 5,000 feet of Panjal lava-flows and ash-beds, which occupy the central part of the basin and overlap the boundaries of the two former series. In the crest of the syncline, at 13,000 feet altitude, a small outlier of thin flaggy shales and limestones occurs, representing the Zewan stage, and passing conformably up into well-bedded, massive, grey limestones of Triassic age. No good, identifiable fossils occur in these series, as can be judged from the numerous slipped blocks, landslides, etc.; the actual outcrop, situated upon bare, craggy lava precipices, is for the present inaccessible.

The belts of arenaceous and strongly quartzose sediments lying in the Dogra slate of eastern Mansehra, which were referred tentatively to the Gondwanas last season, have been found to extend into the Kaghan valley. This rock-series has been examined in more detail but its field relations at any rate for a considerable part of this belt—as well as its microscopic examination do not support the inference of Gondwana age. The high grade of dynamic metamorphism generally seen in some members of this group, *e.g.*, in the thinly foliated quartz-schists and mica-schists, seems to indicate an older age. At the same time, the apparently conformable passage of these sediments at Jured into the Agglomeratic slate would, for part of the series at least, favour the supposition of an age close to that of the Panjal volcanics. Their relations to a strong basal conglomerate, which has several points of affinity with the Blaini conglomerate, may, according to one set of opinions, support this view. Mr. Wadia suggests that the more quartzose

members are probably of Devonian age the Hazara representatives of the Muth quartzites of Kashmir—but further field work is necessary before the question of the correlation of these sediments, which are admittedly easily separable from the Dogra slates of Hazara, can be settled satisfactorily. For the present it will be convenient to designate this formation by the non-committal name of Jured. It is possible that representatives of two or more distinct formations exist in the wide belt crossed by the Batrasi pass and its homogeneity may be only an apparent one, brought about by a copious injection of granite.

Salt Range, Punjab.

During the latter half of the field-season, 1928-29, Mr. E. R. Gee continued the detailed re-survey of the Salt Range. The sections of the uppermost beds of the Salt Marl series as exposed in the Khewra gorge were examined, in an endeavour to corroborate Mr. R. van Vleck Anderson's reported discovery of fragments of dicotyledonous leaves.[1] A second visit was paid to this locality, in company with Dr. Cotter, but on neither occasion could evidence be found to substantiate this fossil find.[2] From Khewra, Mr. Gee continued to Jutana (32° 43′; 73° 9′ 30″) and mapped eastwards along the scarp and the southern edge of the plateau, from Chhammal mountain in the west to Mariala in the east, including the eastern half of Sheet 43 H/2, extending the mapping of Chambal ridge to the north of Jalalpur (32° 40′; 73° 24′ 30″). Sheet 43 H/6 was completed. Returning to Ara (32° 45′ 30″; 73° 13′) Mr. Gee continued the mapping of the Pind Dadan Khan *tahsil* portion of Sheet 43 H/1, and of sheet 43 H/5, working westwards to the Chel and Karangal ridges in the southwestern corner of Sheet H/1; the northwestern corner of Sheet 43 H/2 was also surveyed.

About half-a-mile north of Khewra village, the clay-shales of the lower part of the Purple Sandstone series come in above the uppermost beds of the Salt Marl group. In this locality, on the east side of the glen, the beds capping the Salt marl include the following succession in descending order:—

5. Dull-red gypsiferous marl, including masses of white and pink gypsum. Thickness variable.

[1] *Bull. Geol. Soc. America*, Vol. 38, p. 672.

[2] Since then, however, Mr. Gee has found a small piece of fossil wood and recognisable nummulites in red marls which have always been regarded as part of the Saline series.

4. Khewra trap 7 ft. 9 ins.
3. Greenish clay, with dark inclusions; it also includes some crystals of selenite and sandy dolomite bands. Thickness 1 ft. 6 ins.
2. White and grey dolomite, finely bedded, sometimes cherty, including bands of black bituminous shale, two such bands being prominent in the lower 3 feet. The dolomite is irregularly jointed, and is sometimes very friable; the shale cleaves easily. Selenite films are included within these shales. Total thickness 6 ft. 6 ins.
1. Decomposed white and grey, bedded, fine sandy dolomitic rock, usually very friable. Thickness 11 ft.+Red marl.

The succession of strata was carefully examined for fossils without success.[1] Yellow dendritic markings occur along some of the cleavage-planes of the bituminous shales. On the bedding-planes of certain of the undecomposed strata in Zone[1] were noted dark markings which might possibly represent the remains of fossilised organic matter; on the other hand they may have been merely the result of infiltration along the cleavage and bedding planes. Similar beds, though varying in thickness, were examined on the west side of the gorge.

The general succession of the strata of the Jutana-Chanuwala area was noted in the General Report of last year[2]. Followed eastwards along the scarp and southern edge of the plateau, to Jalalpur, the lower groups—Salt marl, Purple sandstone, Jutana dolomite, and Neobolus shale remain very constant in occurrence, whilst the overlying strata, comprising the Salt Pseudomorph group, Talchir boulder bed, and the Nummulitic series, gradually diminish in thickness. The Nummulitics, about 125-150 feet thick to the north of Ara, thin fairly rapidly eastwards, and finally die out just east of Lambi Lohi in the northwestern corner of Sheet H/6. The variegated sandstones and pisolitic clay bed beneath the coal horizon at the base of the Nummulitics, also disappear in this locality. The Talchir boulder beds below vary in thickness in the eastern part of Sheet H/2, below the Ara plateau. The boulders included are often well facetted, and comprise a great variety of types. In general the thinning to the east is gradual and, except for occasional

[1] See note on p. 141.
[2] *Rec. Geol. Surv. Ind.*, Vol. LXII, Pt. 1, p. 159, (1929).

large pebbles resting on the uppermost Salt Pseudomorph beds to the north of Thil (32° 42′; 73° 20′), the Talchirs also die out a short distance east of Lambi Lohi. The Salt Pseudomorph beds are exposed in considerable thickness—several hundred feet—in this Lambi Lohi area and to the west, but above Thil these strata thin rapidly. North of Jalalpur, on the west side of the Kahan Kas, these beds still form a prominent bright red band resting on the Jutana dolomite (Magnesian Sandstone group) of Mangal Dev, but to the east of the Kahan Kas, in the Chambal ridge, the group is absent. Resting on the Nummulitics to the west and the Salt Pseudomorph beds to the east, are the Tertiary sandstone and clay beds, with conglomerates in the upper part. These beds form the northern slopes of the range, south of the Bunhar river of Sheet 43 H/6, and cover a wide area north and east of the Ara-Umrila plateau of Sheet 43 H/1; they are again well-exposed to the south and east of the Chambal ridge in the eastern part of Sheet 43 H/6. The greater portion of this Tertiary sequence belongs to the Siwalik group, but at the base—usually with a basal conglomerate of yellow nummulitic pebbles, or a grit full of nummulites, up to several feet thick—is a succession of massive, moderately hard, fine, dull green sandstones, with intercalations of grit and pseudo-conglomerate. With these arenaceous beds, bands of purple and purple-red shales, and clays, together with some bands of brighter red clays are interbedded. These massive sandstones, being harder than the true Siwalik types above them, form very prominent dip slopes on the north side of the range and the north and east sides of the Ara-Umrila plateau. Mr. Gee notes that these basal sandstones of the Salt Range are somewhat softer in texture, than those of the northern areas, that the purple clay-shales of the Salt Range 'Murrees' are less shaly and indurated than those of the true Murrees, and that the red clays which are included in the Salt Range beds appear to be absent from the typical Murree group. On purely lithological grounds, it is suggested that these Salt Range strata, belong either to the uppermost Murree horizons, or represent a series of beds transitional between the true Murrees and the Kamlials. In this connection Mr. Gee notes that to the west of the Umrila plateau, in the western slopes of the ridge of Mt. Chel, it is very difficult to separate these lower Tertiary beds into a lower or Murree and an upper or Kamlial horizon. The intervening tract between Umrila and the Mt. Chel area requires further examina-

tion in order to prove whether the change is due to lateral variation in these supposed Murree beds, or whether the latter zone has died out to the west, in which case the beds seen in this Rakh Drengah area should all be put in the Kamlial subdivision. These basal Tertiary sandstones include numerous pieces of silicified fossil wood and bone-fragments; one well-preserved tooth was also discovered.

As we rise in the Siwalik series, the sandstones become softer in texture, and of lighter tints. The Kamlial group, followed by the red clays of the Chinjis, is fairly well-defined. The Chinji-Middle Siwalik boundary is somewhat less definite, whilst the change up into the Upper Siwaliks is very gradual. Mr. Gee takes the uppermost bed of massive grey-coloured sandstones as the top of his Middle Siwaliks. These divisions fall in very well with the earlier mapping of the Siwaliks by Dr. Pilgrim.

Within the greater part of Chambal ridge, to the north of Jalalpur, the Tertiary sandstones rest immediately on the Magnesian Sandstone beds, a thin basal conglomerate, including rounded nummulitic pebbles, usually intervening. The magnesian sandstones are here much thinner than to the west, and in some cases absent altogether.

In the northwestern corner of Sheet 43 H/2, and the southwestern part of 43 H/1, certain lateral changes were noted in the lithology. Mr. Gee observes that the Salt Pseudomorph beds thin, also, to the west of the Ara plateau, being represented by a very thin band of red flags and shales around Mt. Chel and Karangal. On the other hand, the Talchir beds above them, thicken considerably, and above the thick boulder-bed, massive and shaly yellow and green sandstones and grey shales, slightly carbonaceous, are exposed in some sections. The pisolitic hæmatite band at the base of the Nummulitics is usually persistent, and the thin impure coal-seam immediately above has been exposed in several diggings, just below the thick Nummulitic limestones which form the Basharat-Umrila-Ara plateau. These Nummulitics are about 250 feet thick in these western areas.

The detailed mapping of this eastern part of the Salt Range has revealed a type of structure, the presence of which, although predicted by various writers in the past,—Sir Edwin Pascoe in particular,—had not been established in the previous geological surveys of the area. Mr. Gee refers to the overthrust and fold-fault struc-

tures of the Jalalpur-Chambal ridge areas of Sheet 43 H/6. He is convinced that the repetition of the strata and the attending complications of this southeastern corner of the range, are the results of compressive forces—as distinct from tensional stresses—acting in various directions in the different localities. In the first place it should be mentioned that the Purple Sandstone series underlies the Neobolus shales, and no evidence of an overthrust between these two groups of strata is discernible. The Purple Sandstone-Magnesian Sandstone strata continue along the scarp slopes to the east of Baghanwala as far as Jalalpur. A short distance east of Pipli, purple-red marls with massive gypsum and dolomite in the upper part, come in below the purple shales which underlie the massive Purple sandstones, and these uppermost Salt Marl beds thicken to at least 100 feet above Chitthi, but thin out again to the east below the peak of Mangal Dev. These beds dip at about 30° into the scarp slopes, and are underlain in the lower slopes by a thin series of grey sandstones and light-brown clays indicating a Middle Siwalik horizon, dipping beneath the gypseous marls at a moderate angle. The junction between these Siwalik and upper Salt Marl beds appears to be definitely an overthrust or inclined fold-fault in which a considerable movement southwards has taken place. In the lowest slopes, almost vertical Upper Siwalik conglomerates come in, and dip steeply to the south above Jalalpur village. To the west of the Kahan Kas, which intersects the range to the north of Jalalpur, further evidence of repetition by overthrusting is observed, particularly in the eastern slopes of Chak Jalal Khan, where the Salt Pseudomorph beds—here very thin—and the Magnesian sandstones are repeated at least five times; these imbrications die out rapidly both to the east and west. In the vicinity of the Kas the structure is very complicated. The outcropping strata are mainly of the Siwalik horizon but are intersected by a narrow, almost vertical, sheared zone, consisting of irregular outcrops of gypseous marl, Purple sandstones, Neobolus shale, and Magnesian Sandstone beds. The beds comprising this 'tear-zone' link up these outcrops above the overthrust of the southern slopes of Mangal Dev, with those of the southwestern end of Chambal ridge. From this southwestern end of Chambal ridge another zone of steeply-dipping, somewhat shattered Palæozoics and gypseous marl, runs in a westerly and northwesterly direction connecting up with the exposures of

these older rocks around Dhok Chanda and Naghial. Against the western side of these Palæozoic outcrops the Siwaliks from the northwest—between the main ridge of the Salt Range and the Bunhar river—end abruptly. These Siwalik beds swing round rapidly to the northwest and dip almost vertically against the Purple sandstone and Cambrian strata.

Within the western slopes of Chambal ridge the older rocks are again represented, dipping to the east at moderate angles. Evidence of overthrusting was again noted in the exposures at the foot of the western scarp of the ridge. Palæozoic rocks, mainly Magnesian sandstones, form small foothills to the west of the outcrops of gypseous red marl, and in several cases these beds are seen to underlie the gypseous marls. In one section a thin band of lower Tertiary sandstone, of Murree type, rests on the Magnesian Sandstone beds of the foothills, and dipping at about 30° to the east, was observed in one small stream-section, definitely to underlie the red marls of the Salt Marl series. It is difficult to explain such exposures except by regarding the Salt Marl beds as overthrust on to these Tertiary sandstone and Magnesian Sandstone strata.

From the detailed mapping of the above noted areas, Mr. Gee observes that the rocks of this eastern part of the Salt Range were influenced by great compressional stresses at a very late period of the Tertiary epoch, resulting in the complicated overthrusts and tear-faults of the area. The fact that in all these phases of movement the Salt Marl series, together with the Purple sandstones, Cambrian beds, etc., acted in every case, as one large group of strata, is a point which will require further investigation and explanation if a Tertiary age is to be assigned to the Salt marl.

A short distance east of Baghanwala, in the northeastern corner of Sheet 43 H/2, the Palæozoic strata of the scarp slopes are repeated by normal faulting; in the lower slopes there was some indication of the overthrusting of a thin zone of Salt marl on to the Purple sandstones. At Mt. Chhammal in the middle part of Sheet 43 H/2, an overthrust or reversed fault, dipping steeply at an angle of about 60° to the northwest, repeats the succession.

Over the greater part of the scarp the dips are to the north into the hill-slopes, but to the west of Chanuwala and Mt. Chhammal they are to the west, again towards the plateau. Proceeding towards the plateau, Mr. Gee notes that the strata are much more gently inclined, the Nummulitics—in many places almost horizontal—

capping wide areas. This plateau region, has, however, been complicated by a number of steep flexures—usually monoclines with a steeper western limb—running in a general north-inclined-easterly direction. These flexures die out to the north. Other less prominent low anticlines cross them in an east-north-easterly direction, and within the cores of these structures the older beds crop out. The ridge of Mt. Chel in the southwestern part of Sheet 43 H/1, represents one of these steep monoclines overfolded slightly to the W.N.W. The axial beds, comprising the upper part of the Purple sandstone and the Cambrian series, are also affected by small cross-faults, which do not appear to disturb the newer strata in either limb. In the Karangal ridge the older beds are again exposed and are cut off by the continuation of the Diljaba thrust or fold-fault of the western slopes. Mr. Gee suggests that this fold-fault is a complicated structure resulting in imbrications in the areas adjoining the main dislocation. Time, however, did not permit of his mapping the western slopes of the Karangal ridge in detail.

Attock District, Punjab.

Sub-Assistant H. M. Lahiri continued westwards his survey of the Attock district, Punjab, so as to complete the geological map of the Punjab portions of Sheets 42 C/2 and 38 O/14. In January he returned to Calcutta to take up palæontological routine work.

The geological formations mapped in the area consisted of the Nummulitic and the Murree series and alluvium. The Nummulitic forms the cores of compressed anticlinal folds flanked by Murree rocks and occurs in narrow elongated outcrops which are confined to the hilly tracts to the north of Pari (33° 39′; 72° 2′) in 43 C/2 and to the south of Dandi Jaswal (33° 37′; 71° 59′) in 38 O/14. Although the Nummulitics in the two areas occupy the same stratigraphical position immediately below basal Murree beds, they present many lithological and faunistic peculiarities and seem to belong to different horizons in the Eocene succession. The Pari Nummulitic (Sheet 43 C/2) is the typical 'Nummulite Shale' of the Chharat sequence which contains a fauna of Khirthar or Lutetian affinities. But the Dandi outcrop (38 O/14) is essentially a limestone and shale formation, the topmost bed of which is a rather thick, massive limestone full of *Alveolinæ*—a bed unknown in the Chharat Eocene. The fossils obtained from the upper beds of the Dandi Nummulitic included *Assilina granulosa* d'Arch, *Assilina*

spira de Roissy, *Nummulites atacicus* Leym., and *Alveolina* cf. *subpyrenaica* Leym., an assemblage which, with the exception of *A. spira,* shews a relationship to the Laki of Sind. The tentative correlation of the Dandi Nummulitic with the limestone and shale horizon which underlies the 'Nummulite shale' stage of the Chharat area, confirms the views of Mr. E. S. Pinfold, who also regarded the massive limestone forming the topmost Nummulitic bed at Panoba and other areas further to the west as equivalent to this horizon. This correlation, if confirmed by a later more detailed examination of the fossils, will be of interest as pointing to the existence, in the Nummulitic-Murree succession of the Dandi area, of a stratigraphical gap wider than that found in the same succession in the Kala Chitta foot-hills.

According to Mr. Lahiri the Murree series which overlies the Nummulitic is exposed in the area in all its three stages. Lithologically, the Murree rocks are similar to those in the adjacent areas to the east described in the previous seasons' reports.

The general strike of beds in the hilly tract to the north of Nara (33° 38′; 72° 3′) in 43 C/2 is approximately N.W.-S.E. and the dips which average 60° are mostly northerly. A notable structural feature in this area is that of an elongated synclinal basin occupied by Lower Murree rocks. By reason of its being composed of an elliptically-disposed range of strike-hills this constitutes a remarkable feature in the topography of the country to the north and north-east of Nara.

The Murree beds exposed in the *cis*-Indus portion of 38 O/14 have a general E.-W. strike. A compressed pitching anticline with a core of almost vertical Nummulitic rocks, occurring to the south of Dandi Jaswal, forms a prominent structural feature. The only other that deserves mention is a small dome noticed in Upper Murree beds about 1½ miles to the west of Mari (33° 31′ 30″; 72° 30′). This is an asymmetric anticline, the beds on the northern limb of which dip to the north at about 35° while the dip on the southern arm is 60°; the latter, however, steepens rapidly southwards from the crest. The longer axis of the dome, which is directed roughly E.-W., pitches at about 25° westwards but to the east the pitch is abrupt, being 60°. The structure is not unfavourable for the accumulation of oil, but the very small extent of the domefold at the surface and the steepness of the dips on its southern

and eastern limbs, limit the chances of finding any workable quantities to something very small.

The area apportioned to Sub-Assistant P. N. Mukerjee lay partly in the Talagang and partly in the Pindigheb *tahsils* of the Attock district (sheets 43 C/3 and 43-D/5).

The Middle Siwaliks of sheet 43 D/5 (Talagang *tahsil*) consist of the usual dark-coloured, hard, compact sandstones interbedded with red, buff and orange clays; pseudoconglomerates and true conglomeratic pebble beds are often found. The beds, sometimes almost horizontal, but generally dipping very gently to the north, form the southern flank of the Soan geo-syncline. No vertebrate fossils capable of identification were found except some fragmentary *Hipparion* teeth, crocodilian bones and bovine teeth perhaps referable to *Tragoceras*. The alluvium mapped may be classified into Older and Newer; the former, occupying plateaux and high ground, may attain considerable thickness.

The geological formations met with in Sheet 43 C/3 are the Upper Murrees and the Kamlial, Chinji, and Middle Siwalik stages. In lithological characters, the Murrees resemble the Chinjis so closely, that there is often difficulty in distinguishing them. The Kamlials are dark-coloured, hard, iron-stained sandstones, often associated with red clays. The resistant nature of the Kamlial sandstone distinguishes it from the overlying Chinjis and the underlying Murrees and is responsible for conspicuous ridges that extend across the country often for several miles. The Chinjis consist of soft, whitish and greyish coloured sandstones with red clays and usually coincide with a belt of sunken relief. In the Middle Siwaliks were found fragments of a giraffoid molar tooth, *Hipparion*, and bovine tooth.

The general strike of the beds in sheet 43 C/3 is E.-W. and the dips are generally northerly. This sheet is marked by three—probably four—successive strike-faults. The effect of the first three has been to bring the Upper Murree beds in juxtaposition with Lower and Middle Siwaliks. These strike faults with the exception of the most northerly one, are traceable along the whole width of the sheet. The most northerly fault, which runs north of Thatti Sahidan village (33° 26′; 72° 13′) is traceable westwards for about 8 miles from the eastern margin of the sheet. North of the faults, the beds have a general northerly dip. South of the most southerly of the main strike faults, the Middle Siwaliks are exposed in a pitching

synclinal fold. Between the Thatti Sahidan and Mianwala faults the Murree beds are thrown into an isoclinally folded compressed syncline. Between the Mianwala and Kanet faults there is seen a broad shallow syncline occupied by Chinji beds. The Mianwala and Kanet faults are 4½ miles distant from each other near the eastern margin of the sheet, but, when followed westwards by Mr. Mukerjee, they steadily approach each other until near Jand they are less than 1½ miles apart.

Rajputana.

During the field season the Rajputana party consisted of Dr. A. M. Heron, Officiating Superintendent in charge, and Mr. B. C. Gupta, Sub-Assistant. Dr. Heron worked on standard sheets (Central India and Rajputana) Nos. 118, 119, 120, 121, 122, 143, 144, 145, 146, 147, 148 and Mr. Gupta on Nos. 172, 173, 174, 206, 207, and 208.

In the earlier part of the season Dr. Heron made a detailed examination of the basal beds of the Aravalli system resting upon the older banded gneisses, from Udaipur city south to the southern boundary of Mewar, obtained further indubitable evidence of the erosion unconformity between these two formations, and noted interesting examples of how this relationship can be locally obscured by faulting and intrusion. As a rule the lowest beds of the Aravallis consist of thin grits or arkose, passing up into quartzites. At the northern end of the Sarara inlier of banded gneisses, however, there is a great development of volcanic tuffs, now hornblende-schists, resting directly upon the gneisses. They may be correlated with the series of amygdaloids and hornblende-schists north and south of Dilwara. Upwards they pass conformably into an immense thickness of conglomerates and grits; these again pass up into quartzites and the latter in turn into phyllites. These conglomerates and quartzites form a large triangular area of hilly ground, but die out very rapidly to the south. At the southern end of the gneissic inlier, wedges of the Aravalli basal quartzite are faulted into the underlying gneisses, and the latter run in long tongues between the quartzite ridges.

Dr. Heron notes that, above the basement formations, the Aravalli system consists predominantly of phyllites. The highest state of metamorphism which these attain is that of fine mica-schists with crystals of magnetite and garnet. The degree of metamorphism increases from east to west.

Lenticular ferruginous and siliceous limestones may occur throughout the Aravallis, but are specially characteristic of a broad belt lying approximately between the basal formations and the quartzitic zone. Between the latter and the limestone belt the phyllites are almost devoid of limestones. The quartzites consist of a group of thin but fairly continuous bands, fine-grained, grey in colour and often containing pyrite. To the west of the quartzite zone the phyllites include a few quartzites, but they are irregular and lenticular.

In the area examined by Dr. Heron this year, igneous rocks in the Aravallis comprise veins of aplo-granite and pegmatite, which are rather scarce except to the east of Kherwara, and numerous masses of talc and chlorite-schist which probably originated as magnesian basic rocks.

To the west the Aravallis are succeeded by the Delhi system in the great syncline surveyed in previous years in Ajmer-Merwara, along the strike to the north-east. In the second half of the season the syncline was crossed in two wide traverses, and these were linked up by strike-traverses. Both the Aravallis and the Delhis dip vertically, and the unconformity between them is shown by the way in which the base of the Delhi system cuts, at a low angle, across the strike of the Aravallis. At the places where the base was examined no grit nor conglomerate was seen, the reason for its absence probably being that the phyllites which locally underlie it do not yield material suitable for the formation of pebbles. The lowest beds of the Delhi system consist of several thousands of feet of thick-bedded quartzites, usually felspathic, interbedded with phyllite layers. These pass conformably upwards into biotite-actinolite-schists, notable for the profusion of pegmatite veins which traverse them in all directions. The biotite-actinolite-schists grade upwards into calc-schists, and these again into coarsely banded calc-gneisses and calciphyres.

Dr. Heron remarks, that, as is the case in the Aravallis, the degree of metamorphism increases from east to west. The igneous intrusives in the Delhis belong chiefly to the Erinpura granite of LaTouche and its related dyke-rocks. This granite varies greatly in grain, but is substantially the same in mineral composition throughout. It occurs in all sizes of boss and sill, from the great bathylith of Mount Abu downwards. In the degree to which it is foliated there is also wide variation. The granite itself is biotitic, and the

coarse pegmatites which emanate from it carry both tourmaline and muscovite. Like the pegmatite, it is connected with aplite and microgranite veins.

Mr. B. C. Gupta's work lay principally in the south of the complex of banded gneisses which occupies the central portion of Mewar, with the marginal areas of the Aravalli belts to the east and west of it, which rest on it unconformably.

The banded gneisses consist almost entirely of igneous rocks, which appear in great variety and most intimate intermixture, complicated by appearances of mutual intrusion, and by shearing and foliation. In these circumstances the determination of their relative ages is a most difficult problem. The oldest members of the complex seem to be much foliated biotitic or chloritic schists or granulites, which occur but rarely. Observations in the field indicate that these are distinct from the biotitic granitic gneisses, although the two are characteristically combined, as composite gneisses, by interfoliar injection; it is possible that the biotite- and chlorite schists may represent some form of primitive sediment composed largely of igneous debris. The earliest undoubted intrusives are the granites and granitic gneisses. No intrusive contact could anywhere be detected between unfoliated granite and granitic gneiss, and instances of the two grading into each other have been frequently seen. It is concluded that the bosses, which lie mostly towards the south of the area and in which the rock is little foliated, represent the deeper-seated portions of the magma, and that the banded and foliated gneissic veins are apophyses of these.

The pegmatites and aplites are closely related to the granite, and occur freely in it as syngenetic veins. They also invade the gneisses and form with them composite gneisses. The period of intrusion of the aplites and pegmatites appears to have had a much wider range than that of the granites.

Epidiorites and hornblende-schists, representing basic intrusives, are penetrated by the aplites and pegmatites, but the reverse has not been seen; it is therefore inferred that the basic types are earlier, in general, than the latter.

Quartz veins have probably accompanied all the acid intrusives, and have accordingly had a still wider range in period of intrusion. They have been found to cut all members of the complex, and may be regarded as persisting as the last phase of igneous activity.

To the west of the gneissic complex, the Aravallis which rest

upon it show an unusual development of limestone in addition to the usual phyllites. To the east of Salumbar (24° 8′ ; 74° 5′) the base of the formation is marked, for a distance of about 5 miles, by an anticlinally folded conglomerate, which varies in the width of its outcrop from 200 yards to half a mile. The pebbles are of grey and white quartz, often much flattened, in a micaceous and siliceous matrix.

The limestones are often coarsely crystalline, with bands of tremolite and secondary felspar, and octahedra of magnetite, the degree of metamorphism being higher than is usual in the Aravallis to the north. Lenticular ribs of quartzite are also more numerous in the phyllites than is usual. South and south-east of Salumbar is an extensive area of composite gneiss, consisting of sericitic schists interbanded with granite and pegmatite.

The eastern belt of Aravallis consists chiefly of phyllites, with a narrow but persistent band of false-bedded quartzite along the unconformity between the phyllites and the gneisses. To the south-east both are covered by Deccan trap.

Midway in the gneissic plain, a narrow strip of Aravallis runs through Tana (24° 42′ ; 74° 15′) and Bhindar (24° 30′ ; 74° 11′), in an elongated isoclinal syncline. Grits and arkose, or discontinuous beds of quartzite, flank the syncline, and carbonaceous slates and impure limestones, the former containing kyanite and staurolite, occupy its centre.

In Mr. Gupta's area the Delhi system is represented by two small outliers in the midst of the Aravallis, north-west of Parsola (23° 57′ ; 74° 26′). The pebbles consist of white and grey quartz, in a felspathic matrix, and the rock closely resembles the Delhi conglomerates to the north. The outliers rest successively on different horizons of the Aravallis.

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UPPER TRIASSIC FOSSILS FROM THE BURMO-SIAMESE FRONTIER.—THE THAUNGYIN TRIAS AND DESCRIPTION OF THE CORALS. BY J. W. GREGORY, LL.D., D.SC., F.R.S. (With Plates 1 and 2.)

THE most striking feature in the scenery and geology of southern Burma, between the port of Moulmein and the Siamese frontier, is afforded by the hills and huge monoliths of limestone which rise abruptly from the plain. These rocks contain either few or no fossils, and the age of many of them is not yet determined. The tendency has been to regard them as Devonian or Carboniferous, since the limestones of the Shan States and south-eastern Burma belong to those systems. The shales at Moulmein station, which appear to be younger than the limestones, are Permian. The discovery therefore by Dr. G. de P. Cotter in the limestones on the Burmo-Siamese frontier of fossils that were referred to the Lower Mesozoic and probably the Trias is an interesting addition to the geology of this area. The collection was made in 1921 and has recently been sent to me to describe the corals and arrange for the description and identification of the other fossils. The specimens however are so poorly preserved that it is only from their remote locality and from the light they throw on the stratigraphy of a large region, that they are worth the trouble that has been spent on them. Thanks however to the careful examination of the material by Dr. F. Trauth and Dr. Julius Pia of the Naturhistorisches Museum of Vienna, Dr. G. von Arthaber of Vienna, Dr. L. F. Spath, Dr. J. Weir and Dr. Ethel Currie, the last named of whom has kindly examined the Echinoid spines, the fauna may be regarded as Trias and probably as Norian. The fauna is described in the accompanying papers, some notes by Dr. Spath on the Ammonites being incorporated in the introductory paper.

The limestone that yielded these fossils was called by Dr. Cotter[1] the Kamawkala Limestone from a village beside the Thaungyin River, which there forms the frontier between Burma and Siam.

[1] G. de P. Cotter, The Oil-Shales of Eastern Amherst, Burma, with a Sketch of the Geology of the Neighbourhood. *Rec. Geol. Surv. Ind.*, Vol. LV, pt. 4, 1924, pp. 273-313, pls. 34, 35. J. W. Gregory, The Geological Relations of the Oil-Shales of Southern Burma. *Geol. Mag.*, LX, 1923, pp. 152-59.

The fossils come from three localities, which are marked in Dr. Cotter's map (*op. cit.*, Pl. 35). The southernmost (K 21/415) is in Siam opposite the hill Lewa Taung, 4 miles east of the Mepale oil shale deposits, in connection with the study of which the fossils were discovered. The specimens here were corals, a few brachiopods and lamellibranchs, and fragments of ammonites, sponges and calcareous algae. Lewa Taung is about 4½ miles from the Htichara Forest Bungalow which is at the end of a high limestone range which trends N.W.-S.E. The second locality (K 21/416) is about 19 miles to the north of the first, and is a little east of the confluence of the Taung-u, a stream on the right bank of the Thaungyin, at 17° 4′ N., 98° 27½′ E. Here the fossils were brachiopods and some ammonites. The third locality (K 21/417) is about 2 miles west of the last, and is in the gorge of the Thaungyin below the village of Kamawkala. The best ammonites were found at the two northern localities, but unfortunately their preservation is such that Dr. Spath, who has devoted much care to their examination, reports that "they are really indeterminable. Detailed description would be absurd in the circumstances, but if you like to mention in your general remarks that one (the best) of the K 21/417 lot could be compared to *Choristoceras ammonitiforme*, Gümbel, (*see* Mojsisovics, Geb. um Hallstatt, 1893, Pl. CXXXIV, fig. 1) and that the most favourably preserved of the remains, L 21/416, looks like a portion of a compressed Haloritid, like *Jovites* (*ib.*, Pl. LXXXIV) you are welcome to do so. But the latter is Upper Carnic, the former Rhaetic, so again they do not help".

The limestones include also remains of sponges, crinoid stems, echinoid spines, and sections of a large gastropod, that both Dr. Trauth and Dr. Weir report as indeterminable. The sections cut show the calcareous alga, *Diplopora*, fragments that resemble *Lovencipora*[1] and the specimens which Dr. Pia has described as a new genus, *Holosporella*; also an alga determined by Dr. Trauth as a *Sphaerocodium*.

The other fossils from the northern locality are brachiopods and molluscs which have been described by Dr. Weir. They include the best preserved fossils in the collection and Dr. Weir identifies them as certainly Upper Trias.

[1] *Cf.* P. Vinassa de Regny, Triadische Algen, Spongéen, Anthozoen und Bryozoen aus Timor, in Wanner, Pal. Timor, Vol. IV, pt. 8, 1915, p. 104.

The fossils from Lewa Taung are mostly corals; their internal structure is disappointing for they have been mostly altered into crystalline calcite. As many sections were cut as the scanty material allowed, and in some of them occasional traces of structure helped in the generic identification of the corals. Associated with them were some shells which Dr. Weir and Dr. Trauth identify as the Norian *Rhynchonella bambanagensis* Bittner, and *Chlamys* aff. *valoniensis*, which ranges from the Upper Trias to the Lias.

Some of the fossils from the Lewa Taung were the same as those near Kamawkala, and the limestones at the three localities are probably on the same or approximately the same horizon. It was natural to compare its age with the Rhaetic, but neither of the two Rhaetic corals [1] described by Miss Healy from the Napeng Beds on the railway from Mandalay to Lashio in the Shan States resemble those from the Thaungyin. These corals appear to be more primitive than those of the Rhaetic. I had concluded, before hearing Dr. Weir's opinion of the brachiopods, that the fauna was Upper Trias rather than Rhaetic.

Dr. Cotter refers the great mass which forms the hill above the Htichara Forest Bungalow, to the same horizon as the Thaungyin limestones I spent half an hour trying to find fossils in that limestone, but without satisfaction. It contains structures that are probably organic, but indeterminable. A microscopic section shows one circular lobed body, which is probably a calcareous alga; it might, for example, be an altered *Physoporella* (*cf.* Pl. 2, fig. 7). This Htichara Limestone is however different in character from that along the Thaungyin. Although some of the larger fossils at the Lewa Tung have been altered to calcite, many of the fragments with which it is crowded are perfectly preserved. The limestone is comparatively little altered and is not dolomitized. The Htichara Limestone, on the contrary, has been greatly altered; the carbonate of lime has become crystalline calcite, while the bulk of the rock consists of small crowded crystals of dolomite (*cf.* Pl. 2, fig. 7). The Htichara Limestone appears to be so different in its character as to be probably older. The Kamawkala Limestone, judging by Dr. Cotter's account, appears to form less bold and massive hills than the Htichara Limestone.

[1] *Viz.*, *Isastrea compacta* and *Lophosmilia praecursor*, M. Healey, *Pal. Ind.*, N. S., Vol. II, No. 4, 1908, pp. 86, 87, pl. IX, figs. 62, 63.

The discovery of this Triassic marine limestone on the Burmo-Siamese frontier is of interest as it links the Triassic limestones of Spiti and the Himalaya with those in the East Indies, where they have yielded a rich fauna in Timor. The East Indian Himalayan Triassic fauna is regarded as being so similar to that of the Alps as to prove the former continuity of the sea between them. The East Indian and European Triassic faunas have so many affinities that they also must have been connected, and the Thaungyin limestone indicates the probable route. It is linked to the Himalayan Trias by the Upper Trias limestones of N. W. Yunnan at Likiang-fu and in Chinese Tibet at Janula, of which the mollusca and brachiopods were determined by Dr. Cowper Reed. The fossils from Pahang [1] in the Malay Peninsula which R. B. Newton regarded as perhaps Rhaetic or Norian and which Dr. Weir refers to the lower Carnian, are from the nearest Trias to the south. The Himalayan Trias at Spiti and that of Timor in the East Indies include representatives of stages from the Lower to the Upper Trias. At Thaungyin on the contrary only the Upper Trias, and not more than the Carnian and the Norian, are represented in the collection. So far as the evidence goes it suggests that the Lower and Middle Trias were not present in this area and that the sea reached this locality by a transgression in the Upper Trias, as in northern Yunnan [2] where the Upper Trias contains corals and brachiopods, and the lower Trias is continental, as on many parts of the Pacific coast. Thus the Lower Trias and all or nearly all the Middle Trias are absent from New Zealand [3] or are unfossiliferous there. The Triassic series begins in W. Borneo [4] with the Norian and in N. Sumatra [5] and Alaska [6] with the Carnian. In New Caledonia [7] though there is a local

[1] R. B. Newton, On Marine Triassic Lamellibranchs discovered in the Malay Peninsula. *Proc. Malac. Soc.*, Vol. IV, 1900, p. 131; and J. Weir, On some specimens of fossiliferous sandstone from Pahang, Malay Peninsula. *Geol. Mag.*, Vol. LXII, 1905, pp. 247-50.

[2] J. W. and C. J Gregory, Geology of Chinese Tibet. *Phil Trans.*, Ser. B., Vol. CCXIII. 1925, p. 224, etc.

[3] Trechmann, Trias, N. Zealand, *Quart. Journ. Geol. Soc.*, Vol. LXXIII, 1917, p. 167, opp. p. 237. O. Wilckens, Contributions to the Palæontology of the New Zealand, Trias. *N. Z. Surv., Palæont. Bull.*, No. 12, 1927, pp. 43-46. Wilckens remarks, p. 46, that the Lower and Middle Trias are not known to be present in N. Zealand and the occurrence of the Ladinian is uncertain.

[4] F. Vogel, Beitrage Zur Kenntniss der Mesozoischen Formationen in Borneo. *Samml. Reich. Mus. Leid.*, ser. 1, Vol. VII, 1902, pp. 208-20, pl. 8.

[5] W. Volz, Beitrage zur Geologischen Kenntniss von Nord-Sumatra. *Zeit. deut. geol. Ges.*, Vol. LI, 1899, p. 10.

[6] G. C. Martin. *Bull. Geol. Soc. Amer.*, Vol. XXVII, 1916, p. 685.

[7] M. Piroutet, Etude stratigraphique sur la Nouvelle-Calédonie, 1917, pp. 364, 72, 74, 110, 112, etc.

development of the Lower Trias on the Western Coast, and occasional occurrences of the Middle Trias, the main development is of the Upper Trias which often rests unconformably on the Lower Trias or on older formations.

DESCRIPTION OF THE CORALS.

STYLINA sp.

Pl. 1, Figs. 1, 9 *a.*

On the large block containing many specimens of *Centrastraea* is a coral of which the external characters agree with those of *Stylina.* The corallites are about 1·5 mm. in dia. The walls are well raised and distinct, and are in some corallites in contact, but in most cases separated by an intermediate strip usually about 1 mm. wide. As there is only one specimen it is inadvisable to have a section cut, as in view of the internal condition of other specimens it might not show the structure, and the exterior might be lost. *Stylina* is known from the Upper Trias.

In the centre of the corallites are some small round bodies which are suggestive of pali; if so the coral should be referred to *Stephanocoenia* which is also known in the Upper Triassic; but these bodies appear to be too irregular to be pali. In the absence of more material their nature remains indeterminable and the generic position of the coral therefore doubtful.

Another small specimen of a similar coral was sent to Dr. Trauth and he suggests its comparison with *Phyllocoenia incrassata* Frech, from the Zlambach Beds (Norian) but he remarks that it is too imperfectly preserved for certain determination. It also has an apparently styliform columella. Of the figures by Frech it most closely resembles No. 11, as the raised rims of some corallites are in contact, so that the corallites appear as if united by the wall; but in other parts they are separated by a depression overlying exotheca. The material is inadequate to justify the preparation of sections, so that the genus of this specimen remains doubtful.

STYLOPHYLLOPSIS, Frech, 1890. Kor Trias. Palæntogr., Vol. XXXVII, p. 48.

Type species.—S. polyactis, Frech, 1890. *Ibid.*, p. 48, Pl. XII, fig. 3, Pl. XV, fig. 17-23, Upper Trias, Lower Norian, Zlambach bed and Hallstatt Limestone.

STYLOPHYLLOPSIS THAUNGYINENSIS, n. sp.

Pl. 1, figs. 2-7, 9 *b*.

Diagnosis.—Corallum compound; of short cylindrical or sub-cylindrical branches, that sometimes dichotomize or rise slightly from a small nodular or flat base.

Corallites very irregular in shape, being circular to sub-circular in section but may be sub-hexagonal. Calice is very shallow.

Septa long and thin; in the larger corallites are three full cycles, with some very thin septa of a fourth cycle. The primary and secondary septa are moderately stout and taper regularly toward the centre where those of both cycles join the columella. The septa in places appear dentate, and in some parts show a distinctly synapticular structure. On the upper surface they appear solid, but weathered septa and sections (on the under side of the specimen figured as Pl. A., fig. 4) show the trabecular and perforate structure.

Costae more evenly developed than the septa, and accordingly appear more numerous. A slight projecting rim a little below the calicular edge is present on the outer side of some corallites and is crossed by even ridges like the teeth of a cog-wheel.

Columella large; parietal; the upper part projects in some corallites as a sub-styliform tubercle.

Dimensions.—Corallum, in the nodular specimen, Pl. A, fig. 4, diameter 20 mm. by 12 mm.

Corallites, diameter 4 by 4 mm. (fig. 4); 7 by 8½ mm., 7½ by 9 mm., 5 by 6½ mm., 5½ by 5½ mm.

Septa vary in number between 30 and 60.

Distribution.—Kamawkala Limestone on the Siamese bank of the Thaungyin River opposite Lewa Taung, west of Mepale.

Affinities.—This coral is even more puzzling than most of the Triassic species. The uncertainty regarding them is due partly to their scarcity, partly to the descriptions having been often by men who had no extensive knowledge of Mesozoic corals, and partly as the fauna was in a state of flux and characteristics which were subsequently found to be distinctive of different families were then not well-defined. A redescription of the Triassic corals is much needed.

The species with which I was most tempted to identify the corals shown on Pl. A, figs. 2-7 is *Phyllocoenia subincrassata* Krumbeck,[1] from Buru, the island west of Ceram in the East Indies.

[1] L. Krumbeck, Obere Trias von Buru and Misol, *Palæontogr.*, Suppl. IV, pt. I, If. I, 1913, p. 27, pl. 1, fig. 5.

That coral with its nodular growth, slightly raised corallites which in cross section are circular, elliptical or angular, and its thick wall, and often raised costae on the outer rim, is very similar in general aspect to the combined features seen in these specimens from the Thaungyin. The essential difference is that the septa are shown in Krumbeck's illustrations to be normally Astrean, whereas sections and weathered septa of the Burmese coral are perforate. *P. subincrassata*, moreover, has fewer septa (only 20), and the corallites are more crowded; most of those from Burma are isolated. Krumbeck's illustrations show that his species has a columella which, according to his figure *5a* is parietal and according to his *5b* might be trabecular. The presence of the columella therefore suggests doubt as to the correct generic reference of the species. As far as can be judged from Krumbeck's figures his coral is not a *Phyllocoenia* as now defined. The characteristic feature of the Triassic species that were referred to that genus is their secondary wall; upon that character Duncan [1] founded for them the genus *Coelocoenia* which Volz [2] spelt *Koilocoenia*.

Frech's figures of his *Phyllocoenia incrassata* [3] shows clearly that that species has no columella. The coral from the Thaungyin cannot therefore be included in *Coelocoenia* and owing to the perforate septa are referrable to Frech's *Stylophyllopsis*.

Six corallites are figured to illustrate the variations in this coral, of which Pl. A, fig. 2 may be regarded as the type of the species. At first I was disposed to regard them as including representatives, of more than one species, considering the smaller, thick-walled corallites shown in figs. 6 and 7; as distinct from the specimens shown in figs. 2-4; with fig. 5 as an intermediate form but the differences may be merely individual, and due to different conditions of growth. In the specimen shown in fig. 5, further cleaving of the centre of the corallite after the photograph was taken showed clearly the parietal origin of the columella. *Stylophyllopsis rudis* (Emm.) is shown by Frech to be also very variable. Hence the whole series may be regarded provisionally as one species, but with more material it might be found that more than one species is

[1] P. M. Duncan, Revision of the Madreporaria. *Journ. Linn. Soc., Zool.*, Vol. XVIII, 1884, p. 115.

[2] Volz, Die Korallenfauna der Trias, pt. II, St. Cassian, *Palæontogr.*, Vol. XLIII, 1896, p. 4.

[3] Frech, Kor. Trias, pt. I, *Palæontogr.*, Vol. XXXVII, 1890, p. 30, pl. VIII, figs. 1-14, especially figs. 4, 6, 13, 14.

represented. If so, I should regard Pl. A, fig. 2, as the type form.

Of the six species of *Stylophyllopsis* figured by Frech the Thaungyin coral most nearly resembles *S. lindstromi* Frech.[1] That species differs by being always simple, having a deeper calice, and being larger in size, it being up to 13-16 mm. in diameter, and 26 mm. high, and having from 58-60 septa. The side of *S. lindstromi* is repeatedly constricted by the narrowing of the base of each fresh stage of growth. The apparent costae on the rim around *S. thaungyiniensis* may be due to the constriction at the base of a new growth. *S. lindstromi* has also a less conspicuous columella, but otherwise the external surface of the corallite seen from above is very similar to that of the new species. *S. lindstromi* is a dwarf form of *S. mojsvari*, Frech[2] and has a simple corallum, 60 mm. in diameter, and 120-130 mm. high.

S. caespitosa Frech,[3] which he illustrates by a diagrammatic figure, resembles *S. thaungyiensis* by having a compound flat corallum with a few small raised buds. The corallum is described as "rasonformige" or somewhat turf-shaped. The upright buds in *S. caespitosa* are from 5-7 mm. in diameter and have 16 septa, so it is a much smaller species and the septa are figured as normally astrean. *S. polyactis* Frech,[4] up to 40 mm. in diameter, has from 80-120 septa and it is always simple. *S. zitteli* Frech[5] is either simple or branched, but the compound forms are also the scarcer; it has a thick theca, but the septa are about the same number as in *S. thaungyiniensis*; one specimen (Pl. 13, fig. 15), shows the subhexagonal form seen in one specimen of *S. thaungyiniensis*. (Pl. A, fig. 5.) The corallites are 18 to more than 20 mm. in diameter. The columella is far less developed; it is in fact not apparent in many of Frech's figured sections, though it is shown as a grôup of trabeculae in his plate 13, figs. 10 and 11; he however interpreted them as spines from the inner edges of the septa.

S. rudis Emmrich, 1853,[6] is also a variable form; it often has the septa thickened at their thinner ends; the separate corallites are obconic; and the young buds grow from the margin of the

[1] Frech, 1890 *ibid.*, p. 53, pl. 10, figs. 15-20, pl. 13, fig. 2.
[2] Frech, *ibid.*, p. 52, pl. X, f. 7-14, pl. XII, f. 15, pl. XIII, f. 16.
[3] Frech, *ibid.*, p. 52.
[4] Frech, *ibid.*, p. 48, pl. 12, f. 3, pl. 15, f. 17-23.
[5] Frech, *ibid.*, p. 49, pl. 13, f. 9-15, 17-24.
[6] Frech, *ibid.*, p. 50, pl. 12, f. 4-14.

calice of the older corallite, with what has been called paracidal gemmation.

The *Montlivaltia chonocalyx* Weissermel[1] has, in his figure 7, a resemblance of this species, but specimens with the diameter 4 by 4 mm. and 4½ by 5 mm., have 36-46 septa, and one 7 by 8 mm. in diameter has 70-72 septa; there seems moreover no reason to distrust the generic identification by Weissermel.

Stylophyllopsis timoricus Vin. de R.[2] is a much larger form being 30 mm. in diameter and having 96 septa.

The corals shown on figs. 4-6 resemble some *Thecosmiliae* and especially those figured by Prof. Vinassa de Regny as *T. oppelli* Reuss[3] and his *T. weberi*,[4] for both have features that may represent a columella. Otherwise the small thick-walled calices shown here in Pl. A, figs. 5 and 6 are much like *T. weberi* from Timor.

The *T. oppelli* of Portuguese Timor has a diameter of 4-5 mm. and from 28-30 septa so it would be a somewhat smaller coral. But the septal structure appears to be those of *Thecosmilia* and the extension of one septum into an apparent columella may be due to a crack and vein of calcite. The *T. weberi* is said by Professor Vinassa de Regny to have a distinct Ur-septum; but whatever may be the structure of the axis of that species it has more crowded raised corallites than in the Burmese species.

This new coral has the external appearance of an Astrean, and even in parts of some sections the septa appear solid and complete; but some scattered corallites and some sections show that the septa are synapticular. This coral appears therefore to be one of the stages in the development of the Fungian from the Astrean septum.

CENTRASTRAEA COTTERI n. sp.

Pl. 1, Fig. 8; pl. 2, fig. 9 c.

Diagnosis.—Corallum branching in erect flattened stems which rise from a broad base. The stems are long and narrow, and are nearly uniform in thickness till they taper near the upper end. The

[1] W. Weissermel, Die Korallen des deutschen Muschelkalkes. I. Unterer Muschelkalk. *Jahrb. preuss. Geol. Landes. Berlin* für 1925, Vol. XLVI, 1926, p. 12,.. pl. I, f. 7-8.

[2] Vinassa de Regny, Triadische......Anthozoen......Timor, Pal. Timor, f. 4, pt. 8, 1915, p. 101, pl. LXVIII, f. 1, 2.

[3] *Ibid.*, p. 89, pl. LXIX, f. 7, 8.

[4] *Ibid.*, p. 89, pl. LXIX, especially f. 10, 11.

lower part of the stems is marked by oval depressions due to enlargement of some of the calices.

Corallites small, with thick walls. Septa with well marked synapticular structure; two cycles distinct, of straight thin regular septa.

Dimensions.

Corallum, height	43 mm.
Diameter of stem at upper part	4 mm.
near base	5 mm.
Corallites, diameter at distal end	2·5 mm.

Distribution.—Kamawkala Limestone, Lewa Taung.

Affinities.—This coral, by its thick well-developed walls and the styliform aspect of the columella, has some resemblance to *Stylina*; but the septa are distinctly fungian, and resemble those of *Thamnastraea*. By its prominent styliform columella it agrees with *Centrastraea.*

The oval marks along the stem resemble those of the coral from St. Cassian described by von Münster as *Agaricia ramosa*, which is a branched coral with stems 3 mm. in diameter, but thickening where several branches are united, to 8 mm. across. The *A. ramosa* appears to be a small branched *Thamnastraea*; it has oval flat-topped elevations along the stem, which are nearly 2 mm. across; they have some resemblance to the oval depressions in *C. cotteri*, which are due to solution after the death of the corallites on parts of the stem.

Agaricia ramosa has however much thicker more conspicuous septa than *C. cotteri* and appears to have a less developed columella. The stems have been mostly altered internally into calcite, so that the structure of the coral has been obliterated; but one section shows that the septa are similar to those of *Thamnastraea.*

MEANDRARAEA[1] Etallon, 1859, Mém. Soc. Emul. Doubs, ser. 3, Vol. III, p. 528.

Type species.—*M. marcouana* Etallon, 1859. *Ibid.*, p. 528. Corallian (Diceratian), Valfin, E. France.

[1] This name precedes *Latimaeandraraea*, de Fromental, 1861. Introd. Polyp., Mém. Soc. Emul. Doubs, ser. 3, Vol. V, p. 247.

MEANDRARAEA ORIENTALE, n. sp.

Pl. 2, figs. 2-6.

Diagnosis.—Corallum small nodular with a flat upper surface: with the calices separated by low blunt ridges. The ridges are not covered by septocostae.

Calices mostly separate but a few serial rows are due to the confluence of three calices. Simple corallites, subquadrangular, oblong.

Septa often fan-shaped in plan; 3 complete cycles well developed, and some small representatives of the fourth; some of the major septa thickened near the inner end.

Calices shallow.

Columella prominent.

Dimensions.

	Type specimen.		
Corallum ; diameter . . .	14 mm.	40 mm. by	25 mm.
Corallites ; single diameter . .	4 mm.		5 mm.
Serial corallites ; length . .	7 mm.		9 mm.
" " width . .	4 mm.		5 mm.
No. of septa in single corallite . .	34 mm.	about	40 mm.

Distribution.—Kamawkala Limestone. Lewa Taung.

Affinities.—It is advisable to compare this species, with some Triassic *Isastraeae* which in external appearance resemble it; of them it most resembles *Isastraea plana* Laub[1] from St. Cassian, and especially the var. *foliosa*, Frech;[2] but in that variety the serial calices are much more sinuous. In *I. plana* there is of course no columella. Its generic position appears however doubtful, as Frech's description of the septal structure and his figures of the sections (*op. cit.*, Pl. V, f. 5, 6.) both indicate a Thamnastrean Fungian rather than an Isastraean coral. The *Isastraea profunda* Reuss,[3] according to the original figure by von Reuss, has a distinct parietal columella and a simpler plan of the septa. Corallites vary in diameter from 2·5 to 5 mm.; and the calices are; rarely confluent, and there are from 40-48 septa.

[1] Laube, 1865. Die Fauna der Schichten von St. Cassian. *Denk. Akad. Wiss. Wien.*, Vol. XXIV, p. 263, pl. VI, f. 3. Frech, in Volz, Kor Trias, II, *op. cit.*, 1896, p. 53, pl. V, figs. 2-6.

[2] Frech, *ibid.*, p. 54, pl. V, fig. 1.

[3] Von Reuss, Beiträge zur Charakteristik der Kreideschichten in den Ostalpen, besonders im Gosauthale und am Wolfgangsee. *Denk Akad. Wiss. Wien*, Vol. VII, 1854, p. 116, pl. IX, figs. 5, 6.

This corallum resembles the *Isastraea* (*Latimaeandra*) *norica*, Frech,[1] which has larger corallites, as Frech gives the diameter of the individual corallites as 8 mm. and the serial rows as 15 mm. long and 5 mm. wide, and the calices are much deeper and larger. Weissermel's[2] dimensions are stated for the largest calice in a specimen from the Muschelkalk as 13½ mm. by 8 mm.; the diameters of the other calices are 3 to 6 mm.; there are 90 septa in the largest.

The separation of *Isastraea*, *Latimaeandra* and *Thamnastraea* in the Upper Trias is not easy. Triassic corals of this kind were apparently the ancestors of these three genera. The septal characters were intermediate in structure, and some of the septa had dentations which may have given rise to the synapticular of the Fungians.

Among the corals from Timor, this species has some resemblance to the *Isastraea verbeeki*, Vin. de R.,[3] which however has a less serial arrangement of the calices. Many of the Timor *Isastraeae* have no columella and simple astrean septa (*e.g.*, *I. guembeli*, Laube, Vinassa de Regny *op. cit.*, Pl. LXXI, f. 8 and 10); and therefore it may be assumed that the granular aspect of the centre of *I. verbeeki* is not columellar. But that author's *Isastraea gerthi*[4] is represented as having its septa united into a parietal columella.

[1] Frech, 1890, *op. cit.*, p. 21, pl. V, f. 1-5.
[2] *Cf.* also W. Weissermel, *op. cit.*, 1926, p. 18, pl. II, f. 1.
[3] Vinassade Regny, *op. cit.*, p. 97, pl. LXX, f. 1, 2.
[4] *Ibid.*, p. 96, pl. LXXII, f. 6-9.

EXPLANATION OF PLATES

PLATE I.

Stylina sp.

FIG. 1.—Part of specimen, × 8 diameters.

„ 9*a*.—The surface of the corallum, nat. size.

Stylophyllopsis thaungyinensis, n. sp.

„ 2.—Upper view of a corallite of the typical form with well marked costate rim; × 2½ diameters.

„ 3.—A worn corallite, showing that some of the septa are perforate and the nature of the columella, × 2½ diameters.

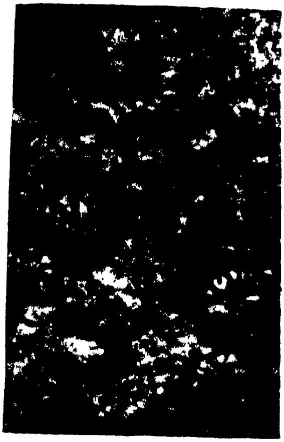

Fig 1 × 8·4.

Fig. 2 × 3.

Fig. 3. × 2·5.

ig. 4. × 2·5.

Fig 5. × 2·5.

Fig. 6. × 4

Fig. 7. × 2·5.

Fig. 8.

Fig 9

/ *D. Filshill, photos.*

G. S. I. Calcutta.

CORALS FROM THE KAMAWKALA LIMESTONE.

Fig 1 × 8

Fig 2 × 2·7

Fig 3 × 2.

Fig 5 × 4·5

Fig 4 × 2·7

Fig 6 × 4·5

Fig 7 × 30

FIG. 4.—A young corallite rising from a flat nodule, of which the lower polished surface shows the perforate nature of the septa and the parietal columella. × 2½ diameters.

„ 5.—A subhexagonal corallite with thick wall and parietal columella. × 2½ diameters.

„ 6. A corallite with two primary septa thicker than the rest and apparently united by the columella. × 4 diameters.

„ 7.—A corallite showing the thick wall and substyliform upper ending of the columella. × 2½ diameters.

„ 9*b*.—A small corallite, on a slab of limestone, nat. size.

Centrastræa cotteri, n. sp.

„ 8.—A branched corallum, nat. size.

„ 9*c*.—A branch, nat. size, on a slab with *stylina* sp. and *stylophyllopsis thaungyinensis*, n. sp.

PLATE 2.

Centrastraea cotteri, n. sp.

FIG. 1.—Two corallites from the top of the same corallum, × 8 diameters, showing the distinct substyliform columella.

Maeandraraea orientale, n. sp.

„ 2.—Surface of corallum, × 2·7 diameters.

„ 3.—Another corallum, × 2 diameters, from slab of limestone with large gastropod and crinoid stem.

„ 4.—Another corallum, × 2·7 diameters.

„ 5.—Part of a thin vertical section showing the septa, × 4·5 diameters.

„ 6.—Part of a thin horizontal section, × 4·5 diameters.

Calcareous Alga, ? *Physoporella*.

„ 7.—Thin section of altered dolomitic Htichara Limestone, from the Htichara Forest Bungalow with a calcareous alga, × 30 diameters. Age probably pre-Triassic. (Hunterian Museum, Glasgow. Col. Z. J. W. Gregory.)

UPPER TRIASSIC FOSSILS FROM THE BURMO-SIAMESE FRONTIER.—BRACHIOPODA AND LAMELLIBRANCHIA FROM THE THAUNGYIN RIVER. BY JOHN WEIR, M.A., PH.D., F.G.S. (With Plate 3.)

PROFESSOR J. W. GREGORY has kindly given me the opportunity of examining and reporting on the brachiopods and lamellibranchs collected by Dr. G. de P. Cotter [1] from the Thaungyin River, in the Amherst District of Burma.

Most of the brachiopods examined are numbered K21·416; they were collected on both banks of the Thaungyin River, about two miles E. of the Kamawkala Gorge, in latitude 17° 3′ 18″, long. 98° 26′ 55″, between Mawpathee and Taungu Chaung, Burma Forest Survey Sheet 456 S.E./4 (C-12-12-21). They are associated with ammonites at this locality (Cotter, *loc. cit.*, p 281, (locality 2)), and are referable to three forms: *Rhynchonella bambanagensis* Bittner, *R.* cf. *fissicostata* Suess, and *R.* cf. *concordiæ* Bittner.

R. bambanagensis is a Norian species of the Himalaya, and *R. concordiæ* is a Norian species of the Alps. Rhynchonellids related to *R. concordiæ* and to *R. bambanagensis* are recorded by Dr. Cowper Reed [2] from the Upper Trias of Chinese Tibet. *R. fissicostata* is a species of the Uppermost Trias in the Alps. The best of the associated ammonites, according to Dr. Spath, is comparable to an Upper Carnian genus. The specimens, both ammonites and brachiopods, are poor, and the determinations must be accepted with caution. The evidence from both groups, however, points to an Upper Triassic age for the Kamawkala Limestone at this locality.

The lamellibranchs come from a locality about 25 miles to the south [3] (K21·415), where they are associated with corals and rhynchonellid fragments. The best of the rhynchonellids is a dorsal valve, probably *R. bambanagensis*; this tends to confirm

[1] G. de P. Cotter: "The Oil-Shales of Eastern Amherst, Burma, with a Sketch of the Geology of the Neighbourhood". *Rec. Geol. Surv. Ind.*, LV, 1924, pp. 280-82.

[2] F. R. C. Cowper Reed: "Report on Triassic, Carboniferous, and Devonian Mollusca and Brachiopoda from Yunnan". In Gregory, J. W. and C. J., "The Geology and Physical Geography of Chinese Tibet". *Phil. Trans. Royal Soc.* Ser. B, CCXIII, 1925, pp. 279 and 280.

[3] Cotter, *loc. cit.*, p. 280 (1).

Dr. Cotter's view that this locality is on the same horizon as the two localities farther north.

The two best lamellibranch specimens are probably *Chlamys.* The ornament is of the same type in both, and they may be interpreted provisionally as belonging to the same form, although they are somewhat discrepant in determinable ribs.

BRACHIOPODA.

The brachiopods are all Rhynchonellidæ. There are 15 specimens (K21·416) in dark compact limestone. The shells are either fragmentary or firmly embedded in the tough matrix, with only portions of the tests revealed. A selection of the brachiopods (six specimens in all) was submitted to Dr. Trauth, who compares them all to *R. fissicostata.* Two of the specimens sent to Dr. Trauth are especially like Suess's species, and with four others (immature specimens) may be determined *R.* cf. *fissicostata.* In external characters these six specimens resemble closely *R. salteriana* Stoliczka, as figured by Bittner from the Upper Muschelkalk of the Himalaya, but as Bittner is doubtful of the Rhynchonellid affinities of this form, the determination *R.* cf. *fissicostata* is preferable to *R.* cf. *salteriana.*

The specimens from K21·416 are referable to three forms; *Rhynchonella bambanagensis* Bittner, *R.* cf. *fissicostata* Suess, and *R.* cf. *concordiæ* Bittner.

In addition to the above there are rhynchonellid fragments (K21·415) associated with corals and *Chlamys* sp.; only one specimen need be mentioned, a dorsal valve, probably of *R. bambanagensis.* Rhynchonellids are also recorded by Dr. Cotter[1] at his locality (3) in the Kamawkala Gorge, associated with ammonites, but I have seen nothing determinable in the material from this locality.

RHYNCHONELLA BAMBANAGENSIS Bittner.

Pl. 3, figs. 1 and 2.

Rhynchonella bambanagensis, Bittner, 1899. "Trias Brachiopoda and Lamellibranchiata". *Pal. Indica*, Ser. XV, III, p. 44, pl. VIII, fig. 4, and p. 56, pl. IX, fig. 18.

Rhynchonella bambanagensis, Diener, 1908. "Ladinic, Carnic and Noric Faunæ of Spiti." *Pal. Indica*, Ser. XV, V, p. 128, pl. XXIII, fig. 8.

Rhynchonella ? sp., Cowper Reed, 1925. *Loc. cit.*, p. 279.

[1] *Loc. cit.*, p. 281.

Two specimens in tough limestone. Only the ventral valves are revealed. These are convex, subrhomboidal, about as broad as long. On one 11 ribs can be counted; the total number would be 14 or 15. The lateral ribs curve slightly outwards on the flanks, and the cardinal rib is much smaller than the others. A shallow sinus is present, comprising three ribs. Asymmetry is expressed in the intercalation of an additional rib at some distance from the beak on the right flank (ventral valve facing the observer). In the other specimen only ten ribs can be counted, but others are probably concealed in matrix on the flanks. The sinus is more strongly defined on the left (ventral valve facing the observer) than on the right, where it passes imperceptibly into the flank.

The actual apex of the beak is indeterminable in both specimens, but the ribs are strongly developed close up to it. In this respect these specimens agree more closely with Bittner's specimens from the beds with *Spiriferina griesbachi* than with his specimens from the *Hauerites* Beds.

The indeterminable specimens (Hunterian Museum, Glasgow University) from Yunnan recorded by Dr. Cowper Reed as *Rhynchonella* ? sp. probably belong to *R. bambanagensis* or to a closely related form. They agree with the present material in all determinable characters.

Locality. - K21·416. "Thaungyin River", both banks, from exposure between Mawpathee and Taungu Chaung, Burma Forest Survey Sheet 456 SE/4 (C-12-12-21). *See* also Cotter, *loc. cit.*, p. 281 (2).

In addition to the above, some rhynchonellid fragments are associated with corals and *Chlamys* sp. at the locality K21·415 (*see* below, and Cotter, *loc. cit.*, p. 280 (1)). The best of these is a dorsal valve, probably of *R. bambanagensis.*

Distribution.—*R. bambanagensis* is a Norian species. It has been recorded from various localities of the Himalayan region by Bittner, Diener, and von Krafft.

RHYNCHONELLA cf. CONCORDIÆ Bittner.

Pl. 3, fig. 5.

Two fragmentary specimens, each showing portions of both valves, have affinities to *R. concordiæ*, and differ from the other rhynchonellids from the same locality in having fewer and broader ribs.

A *R.* aff. *concordiæ* has been recorded from Yunnan by Dr. Cowper Reed (*loc. cit.*, p. 279). The Yunnan specimen is a weathered longitudinal section and no surface features are available for comparison with the present material. In the number and character of the ribs, however, it is similar to these two Burma specimens.

Locality.—See R. bambanagensis (K21·416).

Distribution.—R. concordiæ is a Norian species of the Northern Alps.

RHYNCHONELLA cf. FISSICOSTATA Suess.

Pl. 3, figs. 3 and 4.

Six specimens are referable to this form. All are fragmentary but two are sufficiently complete for the determination of specific characters. Two other specimens have suffered lateral compression, and the remaining two are fragmentary, young individuals.

The shell is triangular, and the valves are equally convex. Thirteen ribs can be counted on two of the specimens; the total number was probably sixteen. They are strongly curved on the flanks, leaving smooth, large and somewhat deeply excavated areas on the lateral commissures. There is a shallow and feebly defined sinus in the ventral valve; it shows scarcely perceptible asymmetry and comprises four or five ribs. At least one rib in each valve is intercalated at a short distance from the umbo; all the others originate at the umbo and are strongly developed there. The beak is determinable in two of the specimens; in one it is suberect, with large hypothyrid foramen, but in the other (a laterally compressed specimen), it is slightly incurved, obscuring the foramen.

These specimens are longer than those described above as *R. bambanagensis*, and narrower, with correspondingly narrower ribs. In outline the young resemble *R. levantina* Bittner, but the ribs are more numerous than in the Levantine species. The ribs are probably fewer than *R. salteriana*,[1] which has typically about 18, with six in the sinus, but their general character and distribution, and the shape of the valves with their somewhat narrowly trigonal outline, equal convexity, and shallow ill-defined ventral sinus give these Amherst specimens a close external resemblance to Stoliczka's species. In view of Bittner's doubt of the Rhynchonellid affinities

[1] Stoliczka: *Mem. Geol. Surv. Ind.*, V, 1865 p. 41, pl. III, fig. 11, (*non* 12); Bittner. *loc. cit.*, p. 15, pl. II, figs. 14 and 15.

of *salteriana* it is better to refer the Amherst specimens with the cautionary 'cf', to *R. fissicostata,* to which they have a strong external resemblance, especially the specimen with suberect beak (Pl. 3, fig. 3).

Locality.—See R. bambanagensis (K21·416).

Distribution.—R. salteriana is a species of the Himalayan Upper Muschelkalk.

LAMELLIBRANCHIA.

CHLAMYS sp.

Pl. 3, figs. 6, 7.

Two lamellibranchs in the collection probably belong to the genus *Chlamys.* Although somewhat discrepant in size and in the number of determinable ribs, they probably belong to the same form. Both specimens have the margins missing; the original outline is therefore indeterminable, but was probably orbicular or ovate. The ornament is of the same type in both, strong rounded radial costæ, of one order magnitude; 25 of these can be counted in the large specimen, and 36 in the other; they are separated by interspaces which are rather wider than the costæ over the greater part of the surface, but become relatively narrower at the margin of the large specimen owing to the flattening of the costæ; the interspaces show concentric striation.

Dr. Trauth points out their affinities to *Pecten* n. sp. Krumbeck ("Lamellibranchiaten d. Trias v. Timor" in Wanner's Palœontologie *v.* Timor, Lieferung XIII, Abh. XXII, 1924, pl. CXCII, fig. 21). The costal interspaces in Krumbeck's form are wider than in the Amherst specimens. They have also affinities to *Chlamys valoniensis* as figured by Newton[1] from Pahang, but Newton's form has ribs of two orders of magnitude irregularly developed. The second order ribs are almost of the same size as the larger ribs, and the general aspect of the internal impression of *C. valoniensis* from Pahang suggests a shell very similar to the larger of the Amherst specimens.

One of these specimens was recorded by Dr. Cotter (*loc. cit.,* p. 280) as "a Lima-like shell," and *fide* Tipper (Cotter *loc. cit.,*

[1] R. B. Newton: "On Marine Triassic Lamellibranchs discovered in the Malay Peninsula". *Proc. Malacological* Soc., IV, 1900, p.131, pl. XII, fig. 1.

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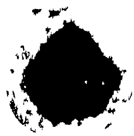

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John Weir, photos. *G S I Calcutta.*

BRACHOPODA AND LAMELLIBRANCHIA, BURMA

p. 281): "There were two ribbed *Pecten*-like lamellibranchs, but the state of preservation was so poor that it was uncertain whether they belonged to *Pecten* or to *Lima*". Towards the margins of the large specimen the ornament recalls *Plagiostoma striata* Schloth., as figured by Goldfuss. The valves of *P. striata* are more convex, however, the flatness of both Burma specimens recalling the left valve of *Chlamys* rather than the usually more convex valves of a *Plagiostoma*.

A third pectiniform specimen with radial costæ from the same locality (K 21·415) has the external surface applied to the matrix. It is indeterminable, but probably belongs to the same form as the other two.

Locality.—K21·415. "Thaungyin River, Siamese bank, S. of 629 height in sheet 517 SW/3, Burma Forest Survey (B-18-12-21)." *See* also Cotter, *loc. cit.*, p. 180 (locality 1).

Distribution.—*C. valoniensis* has a wide distribution in the Upper Trias, Rhætic, and Lias. It has been recorded by Newton (*loc. cit.*), from the Myophorian Sandstone of Pahang, Malay Peninsula, to the south of the present Amherst locality.

EXPLANATION OF PLATE 3.

FIGS. 1 and 2.—*Rhynchonella bambanagensis* Bittner. *Loc.* K21·416.

FIGS. 3 AND 4.—*Rhynchonella* cf. *fissicostata* Suess. *Loc.* K21·416.

FIG. 5.—*Rhynchonella* cf. *concordiæ* Bittner. *Loc.* K21·416.

FIGS. 6 and 7.—*Chlamys* sp. *Loc.* K21·415.

UPPER TRIASSIC FOSSILS FROM THE BURMO-SIAMESE FRONTIER.—ON SOME FOSSILS FROM THE KAMAWKALA LIMESTONE. BY F. TRAUTH, PH.D., CUSTOS PRIV. DOC., NATURAL HISTORY MUSEUM, VIENNA.

MY examination of the fossils belonging to the Kamawkala Limestone on the Thaungyin River, which I have studied at Prof. J. W. Gregory's request, confirms throughout the view expressed by himself and his British colleagues that the material sent me is essentially Upper Trias; but unfortunately I cannot offer a more precise attribution of the localities to any of the Upper Triassic Stages, Carnic, Noric, or Rhætic. Nevertheless it seems to me, from the ammonites and corals, that their age is most probably Carnic to Noric.

My determinations for the three localities separately may be stated as follows :—

I. *Locality.*—K. 21/415, Thaungyin River, Siamese bank, south of 629 feet height in sheet 517 S. W./3, Burmese Forest Survey (B. 18-12-21).

Thecosmilia sp.

Ostrea sp.

Slide of same specimen. Indeterminable fragments of corals and echinoderms.

K 21/415. One large and one small *Pecten* valve radially ribbed, with concentric striæ in interspaces between the ribs. The form reminds me in a certain degree of *Pecten* n. sp. in L. Krumbeck, "Lamellibranchiaten d. Trias v. Timor" (Wanner's "Palæontologie von Timor" Lf. XIII, Abh. XXII, (1924). Taf. CXCII, fig. 21), without however being fully identical with it. It can only be indicated as *aff.* thereto.

K. 21/415. z. On the largest of the rock specimens sent is a longitudinal section of a large gastropod, which is not further determinable. With it are some indeterminable bivalve remains, crinoid stems, and fragments of corals. On the somewhat smaller rock specimen (shown by a red circle) a piece of coral is weathered out which seems to us to resemble *Isastræa* (*Latimæandra*) *norica*,

Frech var. *minor* Frech Die Korallenfauna der Trias, (*Palæontographica*, Vol. XXXVII, p. 26, Pl. VI, fig. 9) from the Upper Trias (Zlambach beds=Noric Stage). Less marked seems to us the resemblance with *Isastræa haueri* Laube (Fauna von. St. Cassian, I, Abth. Spongitarian, Corallen etc. *Denk. Akad. Wiss, Wien. Math*, Nat. Kl., Vol. XXIV, 1865, p. 43, Pl. VII, fig. 1) from the Cassian Beds (Upper Ladinic Stage) of the Southern Alps.

K. 21/415. z. and two slides. Some bivalves which cannot be further determined than *Ostrea* ?, and fragments of corals and two sections of echinoid stems which are oval as seen in oblique section.

K 21/415 g. Crinoid stems and coral remains not more nearly determinable. A specimen of the same number and two slides with remains of *Diplopora*.

These and a thin section which we have cut from a rock fragment, K 21/415, show sections of *Diplopora* which my colleague Professor Dr. J. von Pia has still further investigated (see p. 177 of this part of the *Records*). They show small spherical sporangia on the inner wall of the stem, and resemble *Diplopora phanerosphæra* Pia (*Siphoneæ verticillatæ*, from the Carboniferous to the Lower Cretaceous ; *Abh. Zool. Botan. Ges. Wien*, Vol. XI, (1920), p. 59, Pl. IV, fig. 4), which, according to A. Rothpletz, is said to have originated in the Rhætic of Hindelang in the Alps of Allgäu.

K 21/415 h. Coral remains and amongst them perhaps *Isastræa* (*Latimæandra*) aff. *norica* Frech, var. *minor* Frech ? (Norian Stage ; Zlambach Beds). Also bivalve remains and among them *Ostrea* sp.

K 21/415 w. marked by blue line ; single oblique sections of *Thecosmilia* sp.

Marked by red line : *Phyllocœnia* cf. *incrassata* Frech (*Palæontographica*, Vol. XXXVII, p. 30, Pl. VIII, figs. 11 and 13 ; from the Zlambach Beds, Norian Stage, of the Northern Alps), a small specimen, which unfortunately owing to its imperfect preservation cannot be quite certainly determined.

K 21/415 y. The concentricly striated small knob on the surface of this specimen is manifestly a *Sphærocodium*, an alga, which is very similar to some specimens occurring abundantly in the Cassian Beds (Upper Ladinic Stage) of the Southern Alps.

II. *Locality*.—K 21/416. Thaungyin River, both banks, from exposure between Mawpathu and Taung-u Chaungs, Sheet 456 S.E./4 C.-12-12-21).

Ammonites gen. & sp. indet. Three specimens, which are not sufficiently well preserved for safe generic determination.

Juvavites sp. aff. *bülowi* Dien., 1 specimen. A very incomplete ammonite fragment, which shows only one half of a whorl. It indicates diameter of about 25 mm. and thickness of about 11 mm. The ribbing might be regarded as nearest to a *Juvavites* allied to *J. bülowi* Dien., a species which Diener has determined as of the mixed Carnic-Noric fauna of the Hallstatt-Kalk of the Feuerkogel at the Rötelstein, near Aussee, in the Austrian Limestone Alps. (C. Diener, *Denk. Akad. Wiss. Wien*, Math.-Nat. Kl., Vol. XCVII, (1920), p. 469, Pl. IX, figs. 7a. b.) The suture line is not preserved and unfortunately cannot be used to confirm the above reference.

Rhynchonella sp. aff. *fissicostata* Suess. Six specimens which in form and ribbing have some features that resemble those of *Rhynchonella fissicostata* Suess from the uppermost Trias of the Alps (Kössener Beds, Rhætic Stage); they have however, a still more strongly incurved beak than that species.

Rhynchonella sp. ind. One example which, though very imperfectly preserved, is apparently more coarsely ribbed than the previous form.

III. *Locality*.—K 21/417. From Kamawkala Gorge, Thaungyin River, British side near and west of the Chaung-junction. Sheet 456, S.E./4 (A.-13-12-21).

Ammonites gen. & sp. ind. The weathered remains of some small shells, of which unfortunately not one is generically determinable.

Trachyceras sp. One specimen of an Ammonite which retains a diameter of about 48 mm. Prof. Dr. J. A. von Arthaber, to whom I showed this specimen, regards it as belonging to the genus *Trachyceras*, but its relatively imperfect preservation does not permit of a specific diagnosis. The occurrence of this genus may be regarded as evidence of the Ladinic or Carnic Stage. Yet in view of the certainly Upper Triassic aspect of the scanty fauna of the Kamawkala Limestone we are inclined to regard the horizon of this *Trachyceras* as Carnic.

The aspect of the Kamawkala Limestone resembles in all respects the richly fossiliferous marly limestones of the southern and northern Calcareous Alps, as, for example, the Cassian and Raibler Beds of the Southern Alps, and the Zlambach and Kössener Beds of the Northern Limestone Alps.

UPPER TRIASSIC FOSSILS FROM THE BURMO-SIAMESE FRONTIER.—A NEW DASYCLADACEA, *Holosporella siamensis* NOV. GEN., NOV. SP., WITH A DESCRIPTION OF THE ALLIED GENUS *Aciculella* PIA. BY JULIUS PIA, PH.D., PROFESSOR, NATURAL HISTORY MUSEUM, VIENNA. (With Plate 4.)

AMONG some palæontological material sent by Prof. J. W. Gregory to my friend Dr. F. Trauth for comparison with types preserved at Vienna there was a slide containing a few puzzling fossils. Dr. Trauth presumed they might be algæ and showed them to me. They proved to belong to an interesting new genus of Dasycladaceæ. Our scanty knowledge of other Triassic members of this family from Eastern Asia is summarized in my paper on Dasycladaceæ from the Moluccas (Pia, 1924).

The slide transmitted by Prof. Gregory and a rock-fragment, from which it had been obtained were labelled as follows :—

K 21·415, g Kamawkala Limestone. Thaungyin (Thoung-yeng) River, Frontier of Burma and Siam, N. of Myawadi (ca. NE of mouth of Salwin River). Siamese bank, s. of 629 height in sheet 517 SW/3, Burma Forest Survey (B-18-12-21). Opposite the hill Lewa Taung.

Prof. Gregory and Dr. Trauth agreed in presuming that the age of the rock is Upper Triassic, though the scarcity and bad preservation of the fossil animals in it prevented a sure determination. The fossil alga described below furnishes no evidence bearing on the stratigraphical question, as it belongs to a genus hitherto unknown to science. As will be shown later, all the species susceptible of close comparison with our new fossil are of Triassic age, so that at any rate the result of the palæobotanical investigation is not opposed to the conclusions drawn from the other fossils.

The general shape of the fossil is cylindrical, with a rather thick wall and an axial perforation piercing the cylinder from end to end (or nearly so at least). The wall consists of a single layer of globules. They were originally hollow, with a thin membrane of calcium carbonate. At present some of them are filled with transparent calcite crystals, some with darkish sediment. Obviously the later were already opened, when they were imbedded in the

rock. More worn spheres are reduced to hemispherical depressions on the outer side of the cylinder. The walls of the globules often coalesce, but in some instances one can easily see a dark line separating them from each other.

Measurements.

Outer diameter of cylinder	about	0·4 mm.
Diameter of central perforation	„	0·15 mm.
Diameter of globules	„	0·12 mm.
Thickness of membrane	„	0·01 mm.
Number of globules to be seen on a cross-section .	„	10.

It would be practically impossible to determine the systematic position of this fossil without the knowledge of a single small rock-specimen preserved in the Geological Collection of Munich and containing *Diplopora phanerospora.* I have given a thorough description of this alga in 1920 and a new reconstruction of it in 1926. (*See* also Hirmer's Text-book of Palæobotany, 1927, pp. 72-73). For our present purpose it is sufficient to copy three of my former figures (Pl. 4, figs. 10-12 of this paper) and to draw attention to the following peculiarities. Inside the normal skeleton of *Diplopora phanerospora* enshrouding the axial cell and the proximal parts of the branches there is another tube of calcium carbonate, built up of hollow spheres, just as in our fossil. Its contour is undulating, not straight, but this is certainly only a specific character. I have shown that these globules must be interpreted as the sporangia situated in the axial cell of the alga. This is a primitive condition not observable in recent Dasycladaceæ, but quite general among Palæozoic and early Mesozoic genera.

From a comparison with *Diplopora phanerospora* it becomes obvious, that the Siamese fossil is the sporangial tube of a Dasycladacea otherwise devoid of calcification. Whether this was a *Diplopora* it is not possible to say. For we may safely assume, that very different genera had the same arrangement of the sporangia. Nor is it possible to decide, whether the organs contained in the globules were cysts or free gametes. The living Dasycladaceæ do not behave uniformly in this respect.

The exact age of *Diplopora phanerospora* is not known, though it is probably Triassic.

There is one other fossil alga to be compared with our new species. It is not sufficient in itself to explain the homologies

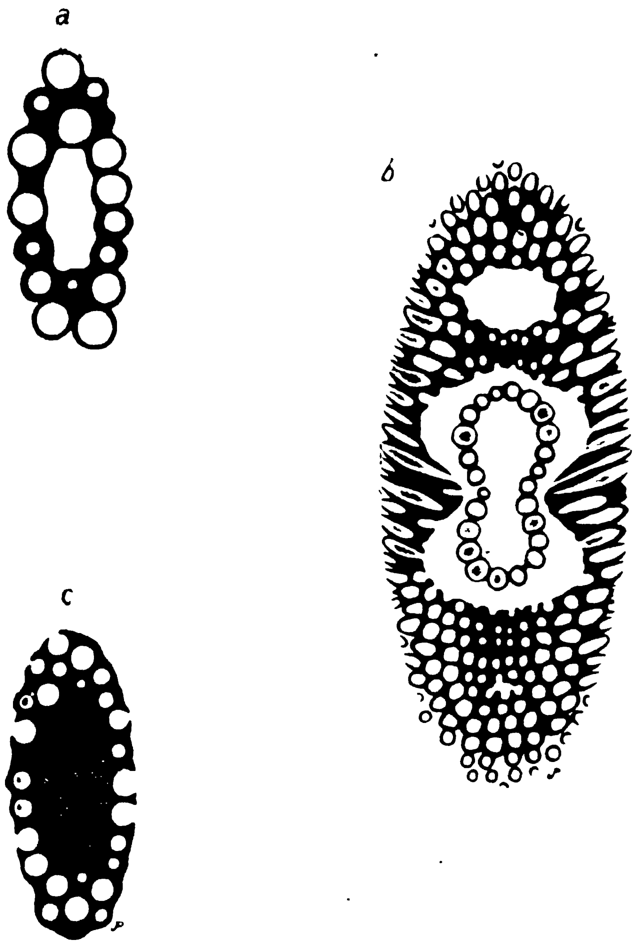


Fig. 1.—Three oblique diagrammatic sections of lime-skeletons, to show the probable homologies.

(*a*) *Holosporella siamensis.* ×80.
(*b*) *Diplopora phanerospora.* ×30.
(*c*) *Aciculella bacillum* ×60.

of the later. But it is of interest to us, because it gives another example of a calcified axial cell-content without outer skeleton, and because its exact stratigraphic position is known. I named this fossil *Aciculella bacillum* in Hirmer's Text-book (p. 86), but no detailed description or figure was given. I take the opportunity to make good this omission.

Aciculella bacillum appears as small, massive rods of carbonate of lime, without central channel. Immediately below. the surface there is a layer of spherical holes. It seems that they opened originally—not only when damaged—on the surface. Occasionally isolated cavities of the same pattern as those just described are to be seen inside the main layer.

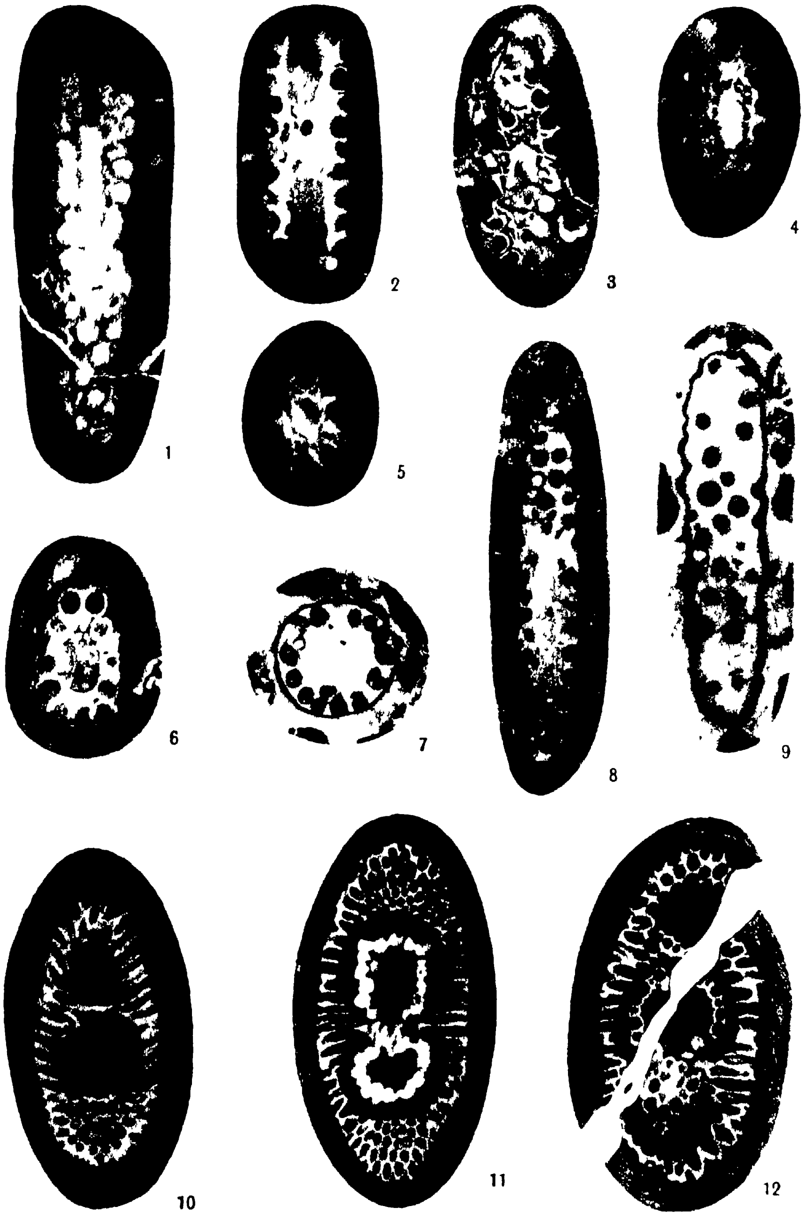
Measurements of Aciculella bacillum.

Diameter of rods	about	0·4—0·7 mm.
„ „ cavities	„	0·1 mm
Number of cavities to be seen on a cross-section	„	15

Aciculella very much resembles *Acicularia*. It is, however, highly improbable, that it had the very specialised organisation of this much younger genus, which seems to have developed from *Terquemella* in late Cretaceous time only. Nor could I detect any trace of a pointed end in my specimens of *Aciculella*. I deem it much more probable, that we have to deal with the content of an "endospore" axial cell. It must be supposed that at the time when calcification began, assimilation and circulation were stopped. The axial cell was gradually filled with lime from the growing point downward, mainly from the supply of material stored in the root-cell. When the alga died and broke to pieces, the gametes or the cysts in which they were contained—escaped from the cavities by the pores.

I obained the rock-specimen with *Aciculella* through the kindness of the late Prof. L. v. Loczy. It was collected by Dr. St. v. Ferenczi in the so-called Chocs-dolomite of middle Triassic age Pia, 1919 at Vagluha, Inovec Mountains in the Western Carpathians. I determined in the same slides *Diplopora annulata*. The Ladinic age of the rock is therefore absolutely certain.

It might be doubted whether the Siamese alga is generically different from *Aciculella*. However, in my first definition of the later genus I considered the lack of an axial perforation to be an essential character. I should prefer to retain this definition as it stands, unless clear proof can be found showing the close resemblance between the two species with respect to the vegetative organs. For this reason I propose the name *Holosporella siamensis* for the alga from the Thaungyin River.



J. Pia, del.

G. S. I. Calcutta

HOLOSPORELLA SIAMENSIS, *nov. gen , nov sp*

I have to thank Prof. Gregory and Dr. Trauth for drawing my attention to this interesting specimen of *Holosporella*; and the Hungarian Geological Survey for lending me the specimens of *Aciculella* as well as much other valuable material.

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EXPLANATION OF PLATE 4.

Each specimen is surrounded in the drawings by a zone of sediment. The skeletons are mostly bright on dark ground.

Figs. 1-6. *Holosporella siamensis* nov. gen., nov. sp. ×35.

1. Nearly longitudinal section. Sporangia and axial perforation filled with calcite.

2. Longitudinal section. Sporangia much damaged. All cavities filled with detritus.

3. Oblique section. Sporangia partly opened; limits between their walls very sharp.

4. Oblique section. Axial cavity filled with calcite, sporangia mostly broken.

5. Cross-section. Preservation like fig. 4.

6. Oblique section. Axial hole filled with detritus.

Figs. 7-9. *Aciculella bacillum* Pia.

7. Cross-section. ×24.

8. Oblique section, nearly axial. ×22.

9. Probably tangential section. ×24.

Figs. 10-12. *Diplopora phanerospora* Pia. Oblique sections, ×10. (Drawings already published in 1920 and reproduced here for comparison).

10. Sterile specimen.

11. Fertile specimen. Sporangia filled with calcite.

12. Fertile specimen. Sporangia opened and filled with detritus.

THE OCCURRENCE OF CRETACEOUS CEPHALOPODS IN THE 'RED BEDS' OF KALAW, SOUTHERN SHAN STATES, BURMA. BY CYRIL S. FOX, D.SC., M.I.MIN.E., F.G.S., *Officiating Superintendent, Geological Survey of India.*

Red beds, consisting of soft sandstones and shales with calcareous conglomerates, are well exposed around the station of Kalaw (96° 35′ : 20° 38′) in the Southern Shan States of Burma. These 'Red Beds' of Kalaw comprise part of C. S. Middlemiss' 'Purple Sandstone Zone' (*Genl. Report of Geol. Surv., India* for 1899-1900, p. 143). T. H. La Touche[1], writing of the Purple Sandstone zone, considered it "to be the equivalent of the Namyau series..... The only difference is the presence in Middlemiss' area, of interbedded conglomerates, of considerable coarseness and thickness, apparently at several different horizons; and of thin seams of coal".

The marine (brachiopod) fauna of the Namyau series has been described by S. S. Buckman[2]. He thought the Namyau series might be divided into two parts—a lower fossiliferous limestone part with brachiopods of Bathonian affinities and an upper unfossiferous part with soft purple sandstones and shales. For the former Mr. Buckman suggested the name *Namyau Limestones* and for the latter *Namyau Shales*. Of these two parts he wrote[3]: "It may be they are two quite distinct formations, differing considerably in date. It may be that the Namyau Shales are not sequential on the Namyau Limestones—that after the deposition of the Limestones there may have occurred the main synclination......with subsequent denudation, antecedent to the deposition of the Namyau Shales."

In 1922 during his examination of the Loi-an coal-field, 3 miles east of Kalaw G. de P. Cotter[4] found the following plant fossils in the coal-measures of Middlemiss' 'Purple Sandstone zone':—

Filicales: *Cladophlebis denticulata* (Brong.).
Gingkoales: *Gingkoites digitata* (Brong.).

[1] *Mem. Geol. Surv. India*, Vol. XXXIX, pt. 2, 1913, p. 306.
[2] *Pal. Indica*, New Series, Vol. III, Mem. No. 2, 1917.
[3] *Ibid*, p. 215.
[4] Unpublished "Confidential Report on the Loi-an Coal-field" by G. de P. Cotter, *Geol. Surv., India*, 1922.

Coniferales: *Pagiophyllum divaricatum* (Bunb.). *Brachyphyllum expansum* (Sterub.).
Bennettitales: *Ptilophyllum* sp. cf. P. (non Otozamites) *hislopi* (Oldh.).
Incertae sedis; *Podozamites distans* (Morris).

Of these fossils Dr. Cotter wrote:—"*Gingkoites digitata* is a cosmopolitan Jurassic species, *Pagiophyllum divaricatum* occurs in the lowermost Cretaceous (Umia) group of Kachh, *Brachyphyllum expansum* (Feistmantel's *Pachyphyllum heterophyllum*) occurs in the Vemavaram beds (age upper Lias to lower Oolite) *Ptilophyllum hislopi* is also found at Vemavaram,[1] while *Podozamites distans* is found in the Lias at Rajmahal. The age of the coal is therefore Jurassic, but it is not yet possible to state whether it is Lias or Oolite..........the fossil flora definitely proves the coal-measures to be later than the Plateau limestone,[2] and close in age to the Namyau series of La Touche, which contain a brachiopod fauna of Bathonian (Lower Oolite) age." Dr. Cotter also expressed the view that the 'Red Beds' of Kalaw were considerably younger than the Loi-an coal-measures and hinted that they might even be Cretaceous in age.

My duties in connection with the coal-fields of Burma took me to Kalaw in January 1929. I was aware of the possible two-fold character of the Namyau series of the Northern Shan States and the probability that Middlemiss' 'Purple Sandstone zone' might have a three-fold character, as it might comprise (1) the 'Red Beds' of Kalaw, (2) the Loi-an coal-measures and (3) the equivalents of the Napeng beds.

'Red Beds' of Kalaw.

At the time of my visit to Kalaw an effort was being made to improve the local Race Course, and, to fill up the hollows in the track, material was being taken from the Red Beds—from the little hillock (with a small pagoda on it) between the Railway Station and the Kalaw Hotel. The strata exposed in the cuttings were very soft, friable sandstones and shales of a purplish red colour. The beds dip westward (*i.e.*, towards the hillock and the Race Course) at about 25°. The section laid bare probably represented 30 feet of the strata. At this place, with the

[1] Jurassic (Rajmahal plant beds) strata in the coastal strip of the Madras (Coromandal) coast.
[2] Upper Plateau limestone (Anthracolithic) is roughly equivalent to the Upper and Middle Productus limestone of the Punjab Salt Range.

help of my interpreter, orderly and a few coolies, I collected two baskets full of fragments of sandstone in which evidences of fossils were visible. Unfortunately the material was exceedingly fragile and easily crumbled to pieces. In spite of the greatest care, only two specimens survived the train and sea journeys to Calcutta. Dr. Cotter, then Palæontologist to the Geological Survey of India, examined these two specimens. He has provisionally recognised them as follows :—No. K 24/865 as *Turrilites* sp. *cunliffeanus* (?) and No. K 24/866 as *Baculites* sp. *vagina* (?) (compare Plates LXXXIX and XCI respectively in *Pal. Indica,* series I and III, Vol. I, 1861-1865). The specific determinations are of course open to emendation, but Dr. Cotter was in no doubt that these Cephalopods were similar to those in the Trichinopoly beds of the Madras Coromandel Coast, which are Upper (Ariyalur) to Middle (Utatur) Cretaceous in age.

Loi-an coal-measures.

The terrestrial flora of these beds have already been discussed and it has been shown that the Loi-an coal-measures are Lower Oolite to Liassic in age. The exact correlation of the Loi-an strata with the Namyau Limestone must always remain uncertain, as the age of the latter is based on a marine fauna. The probability is that they are very close in age. There is thus evidence of shore conditions in Liassic times in the Madras region on the one hand and in the Southern Shan States on the other. Fluviatile conditions were present in the Rajmahal area and, contemporaneously, marine deposition was in progress in the Northern Shan States. The non-recognition of Jurassic strata in Assam and the presence of Cretaceous fossils on the southern margin of the Shillong plateau support Mr. Buckman's idea of a transgression of the sea in Upper Cretaceous times.

Napeng beds.

The age of the Napeng beds of the Northern Shan States was finally established as Rhætic by Miss M. Healy.[1] These beds in the Southern Shan States should therefore underlie Dr. Cotter's Loi-an coal-measures and overlie the Upper Plateau limestone. A series of hard sandstones and conglomerates, quite distinct from the soft 'Red Beds' of Kalaw, occur south-south-west of Legaung (96° 30′ : 20° 50′), roughly east of the Thazi-Kalaw road, about the 38th mile from Thazi. My examination of these beds was very hurried, but there is little

[1] *Pal. Indica, New Series,* Vol. II, Mem. No. 4, 1908.

doubt that they underlie the coal-measures in the synclinal of the Legaung ridge. The Plateau limestones are exposed further west along the railway line from Thazi to Kalaw. Unfortunately I was unable to find any fossils in these sandstones and conglomerates, so that their correlation with the Napeng beds cannot be insisted on. They are, however, older than the coal-measures of the Kalaw region and, in view of the Cretaceous cephalopods much older than the 'Red Beds' of Kalaw.

From the evidence now available the stratigraphical succession of the Mesozoic formations of the Shan plateau may provisionally be classified as follows :—

Age.		Northern Shan States.	Southern Shan States.
Cretaceous	Upper	Namyau Shales.	'Red Beds' of Kalaw.
	Middle		
	Lower		
		Break.	
Jurassic	Upper Oolite		
	Lower Oolite	Namyau Limestones.	
	Lias		Loi-an coal-measures.
		Break.	
Trias	Rhætic	Napeng Beds.	
	Keuper		
	Bunter		Beds at mile 38 Thazi Road.
		Break.	
Permian	Upper		
	Middle	Upper Plateau limestone.	Upper Plateau limestone.
	Lower		

Distribution of Cretaceous beds east of Peninsular India.

Although no Cretaceous fossils have previously been found on the Shan plateau there are records of the discovery of ammonites, of believed Cretaceous forms, in the Arakan Yoma and the Assam hills bordering Burma. W. Theobald[1] secured a single specimen, *Ammonites* (*Schlœnbachia*) *inflatus*, Sow. from near the village of Ma-i (94° 13′ : 19° 20′) in the Sandoway district, Arakan. F. Noetling[2] picked up an ammonite (evidently derived from beds in the Patkoi

[1] *Mem. Geol. Surv., India*, Vol. X, 1873, p. 311.
[2] *Rec. Geol. Surv., India*, Vol. XXVI, 1891, p. 34.

range) in the Hukong Valley. H. H. Hayden found an ammonite in the Naga Hills and recorded that T. H. La Touche had found Cretaceous echinoids in the Lushai Hills.[1] Fossiliferous Cretaceous strata have long been known from the southern scarps of the Shillong plateau about Tharia Ghat (91° 45′ : 25° 11′) and Jowai (92° 12′ : 25° 27′) in Assam.[2] The Cretaceous beds of Trichinopoly[3] along the east coast of Madras have been known for a still longer period. E. Spengler has shown that 50 per cent. of the specimens of the Cretaceous fauna of Assam are identical with species from the Ariyalur group of the Trichinopoly (Madras) beds.[4] Among the more interesting Assam Cretaceous forms are :—

Stigmatopygus elatus from Tharia Ghat and Jowai,
Ostrea (*Alectryonia*) *ungulata* from Sokha and Wahmlein,
Nerita divaricata from Tharia Ghat,
Lyria crassicosta ,, ,, ,,
Baculites vagina ,, ,, ,,
Turrilites (*Heteroceras*) cf. *hornbyense*, Whiteaves, also from Tharia Ghat.

Spengler concluded that both in Assam and in the Pondicherry (Madras) areas the Cretaceous fauna indicated a Senonian age.

General conclusions.

From the fact that the Cretaceous fauna in the Himalayan and Tibetan strata is quite different from that in the rocks of the Assam and Madras areas it must be concluded that these two marine areas were separated by a land barrier in Cretaceous times. This belief is supported by the evidence of the coal seams, suggestive of a shore line, of Upper Cretaceous age in the Garo Hills tract of western Assam.

It is difficult to trace the changes in the distribution of sea and land in this region previous to the Senonian epoch of the Cretaceous period. However, it is clear, from the widespread occurrences of an Anthracolithic (Permian) fauna in Burma and the Himalayan region, followed by the almost isolated position of the Napeng (Rhætic)

[1] *Rec. Geol. Surv., India*, Vol. XL, 1910, p. 288.

[2] *Mem. Geol. Surv., India*, Vol. VII, 1871, p. 181 ; *Rec. Geol. Surv. India*, Vol. I, 1868 ; *ibid*, Vol. VII, 1874 ; Vol. XV, 1882 ; Vol. XX, 1887 ; and Vol. LV, 1924 ; also *Pal. Indica*, New Series, Mem. No. I, 1923.

[3] *Mem. Geol. Surv., India*, Vol. IV, 1862 ; *Rec. Geol. Surv., India*, Vol. XXVIII, 1895 ; *Pal. Indica*, *series* I and III, Vol. I, 1861-65 ; *series* V, Vol. II, 1867-68 ; *series* VI, Vol. III, 1870-71 ; and *series* VIII, Vol. IV, 1872-73.

[4] *Pal. Indica*, New Series, Vol. VIII, Mem. No. I, 1923 (also Kossmat : 'Untersuchungen über die Südindische kreideformation,' III, *Beiträge für Paläontologie*, etc., XI, 1898, p. 134).

marine fauna in the Northern Shan States, that extensive land conditions were prevalent in the early epochs—Bunter and Keuper—of the Mesozoic era. A similarly restricted sea evidently existed in the Lower Jurassic period (as indicated by the marine fauna of the Namyau Limestones) but with the closing epochs of the Cretaceous period a great marine transgression was in progress. This ocean appears to have attained its maximum extent about the time of the eruption of the basaltic lavas (the Deccan volcanic period) in the Peninsular region of India.

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METHODS OF ANALYSIS OF COAL USED AT THE GOVERNMENT TEST HOUSE, ALIPORE, CALCUTTA. BY N. BRODIE, ESQ., M.SC., F.G.S., A.I.C., *Superintendent, Government Test House, Alipore,* with an Editorial Introduction.

INTRODUCTION.*

IN his memoirs upon the coal-fields of India, Dr. Fox has incorporated a large number of analyses of Indian coal kindly provided by the various firms for whom they were done at the Government Test House, Alipore. It seems appropriate, therefore, to take this opportunity to render public the methods of coal analysis adopted at the Test House, and Mr. Brodie has accordingly very kindly written the following paper. Perhaps one comment upon this paper and the custom of the Indian coal trade might be permitted at this point.

It will be seen from Mr. Brodie's paper that at the Government Test House it is the practice, in returning the results of proximate analyses of coal, to exhibit the moisture contents separately from the remainder of the analysis, so that the volatile matter, fixed carbon and ash contents are shown as totalling to 100 per cent.

* By L. L. Fermor.

excluding the moisture. Consequently, in Dr. Fox's Jharia memoir (now in the press) where analyses done at Alipore are reproduced, the same method has been followed; but where analyses from other sources are utilised, Dr. Fox follows the more customary method of including the moisture contents with the constituents that total to 100 per cent. At first sight it may appear that the Alipore practice is the more desirable, because it enables the reader to make a direct comparison of the constituents of coal that possess fuel value, namely, the volatile matter and the fixed carbon. It must be remembered, however, that a portion at least of the moisture of the coal is an inherent constituent of the coal as it is in colloidal association with the other constituents of the coal, as has been shown by myself in two recent papers. It is also true that the amount of moisture in an air-dried sample varies within limits according to the temperature and humidity of the atmosphere. But it does not follow that all the moisture should be excluded from the analysis. It means instead that coal must be regarded as a system, the composition of which varies with the circumstances to which it is exposed. When the coal is utilised as fuel, a proportion of the heat generated by the combustion of the carbonaceous materials is utilised in evaporating the moisture contents of the coal, and, therefore, it appears to some that the inclusion of the moisture contents in the analysis of coal is necessary in order to give a correct view of the economic value of that coal. Assuming that the calorific values of coal at the Government Test House are also carried out on dried coal, it seems obvious that the results obtained are higher than would be experienced in practice, both because 100 grammes of coal as used in practice contain less than 100 grammes of air-dried coal by the amount of the moisture present, and because in practice a portion of the heat generated by the carbonaceous portion of the coal would be utilised in evaporating the moisture contents.

A classification of coals into grades is given in para. 24 of the Coal Grading Board Act, 1925. From the fact that the points mentioned in the various grades are ash percentage, calorific value and percentage of moisture, it would appear that the classification was intended to apply to coals as they actually exist, namely, including moisture. From the notes on p. 6 of the Publication of the Indian Coal Grading Board, 1928, containing a list of graded coals, copies of the Act and Rules and other information (1929), in which attention is drawn to the discrepancy between the calorific value

of air-dried and oven-dried coals in high-moisture coals, and from the fact that the Grading Board describes briefly the method of determination of calorific value adopted at the Government Test House, Calcutta, it appears that for purposes of classification into the grades of the Coal Grading Board, the data determined by oven-dried coals are adopted. This is a more favourable treatment of coals than the Act would appear to have intended and must allot to many coals a considerably higher calorific value than the coal as used possesses and consequently must in many cases allot a coal to a higher grade than would otherwise be the case.

ANALYSIS OF COAL.

The methods of analysis employed in different laboratories for the analysis of coal and also the methods of treatment of samples prior to analysis vary very considerably. The present chapter deals particularly with the methods followed at the Government Test House, Calcutta.

Sampling.

A sample of coal as received at the laboratory should be a fair average of the consignment it represents. To ensure that this is so is not the business of the analyst but of the sampler. The question is, however, sometimes forced on the attention of the analyst, who may in an extreme case receive a single piece of coal as a sample. A single piece of coal cannot represent anything but itself and it is important that all buyers and sellers should be aware that coal is an extremely variable material, even from foot to foot of the same seam. Correct sampling is therefore an indispensable preliminary to analysis. The details of sampling, however, fall outside the scope of the present chapter and it is not proposed to deal with the subject here except to draw attention to its importance.

The representative sample necessarily consists of a large number of pieces of coal which in the majority of cases have already been broken down considerably in the process of sampling. In the laboratory a much smaller sample completely representative of the largest sample, and hence, if all has gone well, of the entire consignment, must be prepared. Many methods of achieving this are in use. In the Government Test House the sample as received is broken

down further and quartered. The operation of quartering consists of collecting the sample into a flat heap, roughly circular in shape, and drawing two lines at right angles through the centre. The heap is thus divided into four nearly equal sectors. Two sectors diagonally opposite are rejected and the other two retained for further treatment. The quartered material, now reduced to half its former bulk, is ground further and again quartered. This process is repeated and the sample thus becomes smaller and smaller and simultaneously finer and finer. The alternation of grinding and quartering is continued until a fraction of suitable size is obtained. This material is then passed through a sieve having 60 meshes to the inch. Any coal retained on the sieve is further ground until all has passed through. The whole is finally mixed thoroughly to obtain the laboratory sample, which weighs about 100 grams.

Proximate Analysis.

The type of analysis most commonly required is a 'proximate' analysis together with the calorific value. Sometimes an 'ultimate' analysis is required, but in most cases this is of little importance to the user. The ultimate analysis means the determination of the composition of coal or other material in terms of its chemical elements, which in the case of coal are carbon, hydrogen, nitrogen, sulphur, oxygen and also ash, although the ash, of course, is not an element. A proximate analysis is one which sets forth the composition of the material on what is frequently a more rational basis, *viz.*, in terms of the compounds or groups of which it is composed. This at least is the formal meaning of the word. In coal analysis it is used in a loose sense, since it is not possible to determine the compounds present. The practical meaning in coal analysis is much less ambitious and in this case the proximate analysis means the determination of moisture, volatile matter, fixed carbon and ash. The volatile matter is the gas given off when the coal is strongly heated and fixed carbon is the coke remaining after deducting the amount of ash contained in the coke.

The four items of the proximate analysis do not even in the case of moisture represent definite chemical entities. They should rather be regarded as arbitrary figures, of which the values, for any given coal, are to a considerable extent dependent on the details of the

method used, which should therefore be standardised as closely as possible. Moisture is generally determined by heating the coal to a definite temperature until it has a constant weight. In addition to the moisture, however, other losses may occur and on the other hand and more important there is a certain oxidation of the coal tending to an increase of weight and hence to an apparent reduction in the percentage of moisture. The determination of volatile matter is much more arbitrary, as the amount of gas given off when the coal is heated depends very largely on the temperature used and on the conditions under which the coal is heated. The ash of coal is also not a definite substance. It does not actually represent the mineral matter originally present in the coal but this mineral matter after it has been altered by incineration of the coal. The quantity of ash obtained may therefore vary according to the method of ash determination employed. The fixed carbon, which is determined by difference, is naturally greatly affected by the variations in the other determinations.

Moisture.

The proximate analysis of coal, as also the ultimate analysis and the determination of calorific value, may be carried out on the sample as received, *i.e.*, after sampling in the manner described (or in some analogous way) without drying. On the other hand it may be carried out on the dried sample or on the air-dry sample. All of these methods appear to the writer to have their disadvantages. The material frequently taken is the air-dry coal, but air-drying is not a very definite stage, since varying humidity and temperature affect the coal moisture content very considerably. At the Government Test House it is the practice to carry out all analyses on the dried coal, since it is considered that this gives the most consistent basis for analysis and is equally appropriate for all types of analyses. The analysis of the same coal carried out at different times should therefore be comparable. For the same reason the moisture content is exhibited separately from the remainder of the analysis, which, therefore, totals 100 per cent. excluding the moisture. In carrying out the analysis the moisture is first determined. About two grammes of the powdered coal are weighed into a weighing bottle and heated in an air oven at a temperature of 105°C. until all moisture has been driven off. This requires about two hours. A modification of this method is required if the coal is exceptionally moist in order to prevent undue loss of moisture during the process of sampling. In this case the sample for the

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The proximate analysis of coal, as also the ultimate analysis and the determination of calorific value, may be carried out on the sample as received, *i.e.*, after sampling in the manner described (or in some analogous way) without drying. On the other hand it may be carried out on the dried sample or on the air-dry sample. All of these methods appear to the writer to have their disadvantages. The material frequently taken is the air-dry coal, but air-drying is not a very definite stage, since varying humidity and temperature affect the coal moisture content very considerably. At the Government Test House it is the practice to carry out all analyses on the dried coal, since it is considered that this gives the most consistent basis for analysis and is equally appropriate for all types of analyses. The analysis of the same coal carried out at different times should therefore be comparable. For the same reason the moisture content is exhibited separately from the remainder of the analysis, which, therefore, totals 100 per cent. excluding the moisture. In carrying out the analysis the moisture is first determined. About two grammes of the powdered coal are weighed into a weighing bottle and heated in an air oven at a temperature of 105°C. until all moisture has been driven off. This requires about two hours. A modification of this method is required if the coal is exceptionally moist in order to prevent undue loss of moisture during the process of sampling. In this case the sample for the

determination of moisture may be taken at a much earlier state of the grinding and must be proportionately larger.

The remainder of the proximate analysis is carried out on about one gramme of the dried coal, which is weighed from a weighing bottle into a platinum crucible of about 30 c.cs. capacity. The crucible is provided with a tight fitting lid, which is nearly closed, leaving only a small aperture for the escape of gas. The crucible is first gently heated over a small bunsen-burner flame. At the end of three minutes much stronger heating is applied by subjecting the crucible to the hottest part of a bunsen-burner * flame 7 inches in height. Some such procedure as this is found to be necessary if a process universally applicable is to be adopted. In some laboratories it appears to be usual to subject the coal immediately to the highest temperature used. This, however, frequently causes loss of coal through violent evolution of gas, some particles of coal being consequently carried away. By dividing the heating into two stages, of which the first is relatively gentle, such complications are avoided with those coals that are apt to give trouble and it does no harm with the remainder. At the end of the second period of four minutes, the crucible is allowed to cool. The lid is removed and the film of carbon adhering to the lid deposited from the gas and a similar one on the side of the crucible are cautiously burned off. The crucible is then placed in a desiccator and when cold is weighed. The nature of the coke given is also examined at this stage. The crucible is now removed to a gas muffle furnace maintained at a temperature of about 1,000°C. in which it remains until the coke has become reduced to ash. The crucible is again placed in the desiccator, cooled and weighed. This gives the percentage of ash, while the percentage of fixed carbon is obtained by deducting from 100 per cent. the amount of ash and the amount of volatile matter.

Volatile matter.

Fixed carbon and ash.

Calorific Value.

The calorific value of a coal measured in C. G. S. units is the number of calories generated by the combustion of one gramme of coal. The calorie is the amount of heat required to raise the temperature of one gramme of water by one degree centigrade. Since

* The bunsen-burner used is $\frac{1}{4}$ of an inch in internal diameter.

the specific heat of water varies with the temperature of the water, the definition is not exact. The error arising in this way is, however, small and the difference is generally ignored. Measured in British units the calorific value is the number of B. T. U. (British Thermal Units) generated by the combustion of one pound of coal. The B. T. U. is the amount of heat required to raise the temperature of one pound of water by one degree Fahrenheit. The ratio of the calorific value expressed in calories to the calorific value expressed in B. T. U. is therefore the ratio of the degree centigrade to the degree Fahrenheit. Hence one calorie per gramme is equal to 1·8 B. T. U. per pound.

The calorific value of coal is generally determined in a bomb calorimeter. The 'bomb' consists of a strong steel vessel fitted with a detachable cover and a valve for the admission of oxygen. The cover carries two electrodes, one of which generally acts as a support for a crucible. The electrodes are carried through the cover in insulated bushes and are provided on the outside with screw terminals. Several types of bomb are used. In the Government Test House three calorimeters are used. Two are fitted with Mahler-Cook bombs and the third with a different type of bomb, which has, however, not proved very satisfactory for calorific values, although it works well for the estimation of sulphur in the manner described below in dealing with ultimate analysis. All bombs require to be lined with an acid resisting material in consequence of the formation of acids on the combustion of coal. The Mahler and Mahler-Cook bombs are lined with an enamel as distinct from the original Berthelot bomb which was lined with platinum. The third bomb mentioned is lined with gold.

About one gramme of coal is used for the determination of calorific value. The portion of the sample used for this purpose is first compressed in a screw press and coheres to form a pellet which is placed in a small fireclay crucible. The crucible is then placed in position on the electrodes. A small piece of thin copper wire is attached to the electrodes and is placed in contact with the coal pellet. The cover is screwed into place and oxygen admitted through the valve until a pressure of 25 atmospheres is reached. The oxygen is obtained from cylinders of the type generally used. The valve is closed and the bomb is removed to the calorimeter. This is a cylindrical copper vessel enclosed in a protecting outer vessel. The arrangement is such as to reduce heat losses to the smallest

practicable amount. The copper calorimeter is not in contact with the outer vessel, but is supported on cork studs. Similarly the sides of the calorimeter are fitted with fibre distance pieces. The outer vessel is hollow and filled with water. It is covered on the outside with felt. The calorimeter itself is filled with about 2,500 grammes of water.

When the bomb is in place wires from a battery are attached to the outer terminals of the electrodes and a cover is placed over the calorimeter. The cover is fitted with a stirring arrangement and holes for the electric leads and for a thermometer. The thermometer is placed in position and the stirrer started. Five minutes are allowed to elapse to establish thermal equilibrium in the system. After that thermometer readings are started and continued for a further five minutes at minute intervals. The change of temperature during this time is small, but its measurement is necessary in order to establish the amount of cooling that occurs throughout the determination. At the end of the second period of five minutes the switch is closed and the current from the battery passes through the copper wire attached to the electrodes. The copper burns in the oxygen and in turn ignites the coal. Readings of the thermometer are continued at half-minute intervals and after a short time a considerable rise is seen. At the end of a few minutes the temperature reaches its maximum and begins to fall slowly. Temperature readings are continued for a further five minutes after the maximum has been reached. All the data are now available for determining the calorific value. The total heat generated in calories is given by multiplying the rise in temperature of the water by the equivalent weight of the water present. The actual weight of water is about 2,500 grammes, but in addition the temperature of the whole bomb and the inner vessel of the calorimeter has also been raised. To allow for this the 'water equivalent' of the whole system must be added to the weight of the water. This equivalent is determined by burning fuels of known calorific value in the bomb. The weight of fuel taken multiplied by its calorific value and divided by the rise of temperature gives the total equivalent weight of water. Deducting from this the actual amount of water used, the water equivalent is obtained.

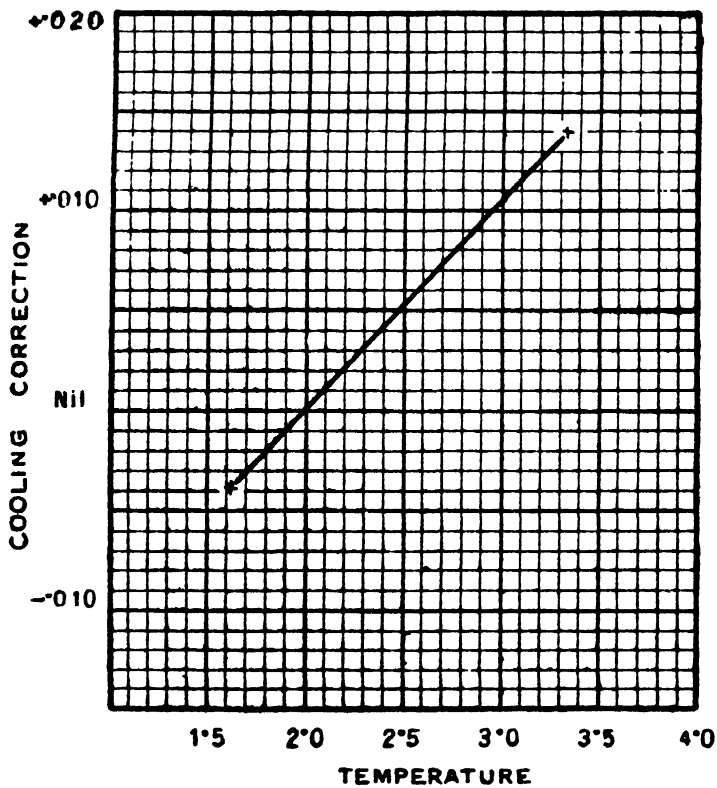
The rise in temperature measured also requires correction. At the beginning of the experiment the temperature of the water in the calorimeter may be slightly more or less than the temperature of

the room so that the water slowly rises or falls in temperature. At the end of the determination the water is normally appreciably warmer than the temperature of the room so that the temperature falls. In the course of the combustion there is smilarly a heat loss or gain. The value of the total loss of heat from this cause is calculated from the figures recorded. The method of calculation may best be seen from a specific example.

Time minutes	Temperature °C.
0	1·601
1	1·603
2	1·607
3	1·610
4	1·612
5	1·620
Coal ignited	
5½	1·880
6	2·770
6½	3·190
7	3·302
7½	3·350
8	3·360
8½	3·367
9	3·368 Maximum
10	3·360
11	3·348
12	3·335
13	3·320
14	3·302
15	3·290

In the first period of five minutes the temperature rises from 1·601°C. to 1·620°C., giving an average of 0·0038°C. per minute. As the correction is made for cooling this is taken as a cooling rate of —0·0038°C. at the temperature of 1·61°C., *i.e.*, the average of the two extremes. Similarly the cooling rate in the final period of five minutes is +0·0140°C. at the temperature of 3·325°C. (*i.e.*, the mean

of 3·360°C. and 3·290°C.). During each of these periods of five minutes the rate of cooling is taken as constant, while for the intermediate temperatures the rate of cooling is taken from a graph. The graph, as shown below, is a straight line drawn between two points representing the two rates of cooling just calculated.



The rate of cooling taken for each minute is that corresponding to the observed temperature at the half-minute. Thus during the sixth minute the observed temperature rises from 1·620°C. to 2·770°C. and the effective mean is taken as 1·880°C., which is the observed temperature at 5½ minutes.

The following corrections are thus made:—

Time minutes	Observed temperature °C.	Correction for one minute °C.	Total correction °C.	Corrected temperature °C.
0	1·601	*nil*	*nil*	1·6010
1	1·603	—0·0038	—0·0038	1·5992
2	1·607	—0·0038	—0·0076	1·5994
3	1·610	—0·0038	—0·0114	1·5986
4	1·612	—0·0038	—0·0152	1·5968
5	1·620	—0·0038	—0·0190	1·6010
6	1·880 (at 5½)	—0·001	—0·020	..
7	3·190 (at 6½)	+0·0125	— 0·0075	..
8	3·350 (at 7½)	+0·0140	+0·0065	..
9	3·367 (at 8½)	+0·0140	+0·0205	..
10	3·360	+0·0140	+0·0345	3·3945
11	3·348	+0·0140	+0·0485	3·3965
12	3·335	+0·0140	+0·0625	3·3975
13	3·320	+0·0140	+0·0765	3·3965
14	3·302	+0·0140	+0·0905	3·3925
15	3·290	+0·0140	+0·1045	3·3945

The object of applying the cooling correction is to eliminate any errors arising from heat entering or leaving the calorimeter and, therefore, if the temperature at each point could be determined with complete accuracy, it is evident that the six initial temperatures calculated would all be identical, as would also the six final temperatures. Actually they are not identical giving some measure of the error inherent in reading the thermometer. The error is, however, reduced by taking the mean of each series of temperatures

so that the system of correction serves a double purpose. The calorific value is calculated as follows :—

Mean of corrected final temperatures		3·3953°C.
Mean of corrected initial temperatures		1·5993°C.
	Rise .	1·7960°C.
Weight of coal	0·884 gramme	
Weight of water	2,500 grammes	
Water equivalent	780 grammes	
	3,280 grammes	
Calorific value	$\dfrac{3{,}280 \times 1{\cdot}796 \text{ gram calories}}{0{\cdot}884}$	
	=6,664 gram calories.	

If the calorific value were determined without taking into consideration the cooling correction it would be 6,486. In some cases the difference is greater than this, since the amount of the correction depends on the relative temperatures of the water in the calorimeter and of the atmosphere.

Other corrections may be applied to the calorific value as determined. The most important is that for the latent heat of steam formed by the combustion of the hydrogen in the coal. The calorific value determined in the manner described is sometimes known as the gross calorific value and that calculated by subtraction of the latent heat of steam is known as the net calorific value. This modification is based on the difference between burning coal in the ordinary way and burning it in a closed vessel. In the latter case the steam formed is condensed giving out its latent heat, while in the former case it passes off as vapour. Corrections are also sometimes made for the heat of formation of nitrogen acids and sulphur acids found in the bomb when the combustion is finished.

The desirability of such corrections is open to doubt. Admittedly the calorific value of fuel burned under laboratory conditions differs materially from the practical calorific value. No corrections, however laborious, can make the two identical and it seems better to accept the fact that the laboratory determination gives an arbitrary value. It seems doubtful whether the practical value is more accurately assessed by making equally arbitrary corrections, which add greatly to the intricacy and expense of the determination.

The type of thermometer used in the determination of the calorific values is of great importance. The thermometer must read

accurately to at least a hundredth part of a degree centigrade and should preferably be capable of being read to approximately a thousandth of a degree centigrade. The most suitable type of thermometer has been found to be the Bekmann. The scale of the Beckmann's thermometer extends over 6°C. and can be adjusted by removing or adding small amounts of mercury to the column. For this purpose a device is contained in the top of the thermometer, consisting in effect of an enlarged portion of the capillary bore of the thermometer. If the thermometer bulb is warmed, mercury flows into this space; and if the thermometer is inverted and tapped, the thread is broken off at this point and on cooling, the thread retracts and contains less mercury than it did before. Conversely, if the thermometer is kept upright and the bulb allowed to cool, the thread will contain more mercury than it did before. The thermometer therefore, although of short range, can be used for any ordinary temperature. The readings recorded, however, are arbitrary and have no relation to actual centigrade degrees in the absolute sense, although a difference of one degree is approximately the same as a difference of one degree in the centigrade scale proper. The fact that the thermometer contains sometimes more and sometimes less mercury makes a small difference to the value of the degree which, however, can be allowed for. The only practical alternative, short of electrical thermometry, to the Beckmann's thermometer is to have a set of thermometers, each of which covers only a short range of temperature. The thermometers ordinarily used in the Government Test House are Beckmann's thermometers, which account for the apparently low temperatures shown in the example given.

Ultimate Analysis.

In the ultimate analysis of coal and of other organic substances, carbon and hydrogen are determined together by combustion. The combustion tube consists of a hard glass tube 36 inches long and $\frac{11}{16}$ of an inch in internal diameter. At one end of the tube a blank space of about 12 inches is left and at the other end a blank space of about 6 inches. In the remainder of the tube are placed copper oxide, made by the oxidation of copper wire, along 14 inches and lead chromate in granular form along 4 inches. These two materials are separated by a partition of oxidised copper gauze and similar partitions are placed at the other end of each. The combustion tube filled in

Carbon and hydrogen.

this way is placed in a gas-fired combustion furnace having an effective length of 24 inches, so that about 6 inches of the tube project at each end. The furnaces used are fitted with 25 burners and each burner is independently adjustable. The furnace is fitted with fireclay tiles which can be brought forward to cover the tube or pulled back to leave the tube open. The combustion is carried out in an atmosphere of oxygen, which must be purified so as to remove from it any trace of water or carbon dioxide. The purifying apparatus consists of a wash bottle containing concentrated sulphuric acid, a calcium chloride drying tower, a large U tube containing soda-lime and a second wash bottle containing concentrated sulphuric acid. Oxygen is passed from a cylinder through this apparatus and then through the combustion tube, so that the current flows first through the larger empty space of 12 inches, then through the copper oxide, the lead chromate, and finally through the smaller empty space of 6 inches. At the other end of the tube is attached an absorption apparatus. This consists of a U tube, containing calcium chloride and fitted with ground in glass stoppers and a potash bulb fitted with a guard tube. The potash bulb contains caustic potash solution, 15 grammes in 20 c.cs. of water. The guard tube contains calcium chloride and soda-lime. The function of the calcium chloride is to absorb the water formed and of the potash to absorb carbon dioxide. Finally, a second guard tube is used, filled with calcium chloride and soda-lime, in order to prevent any absorption of carbon dioxide or water from the air.

A blank determination is first made by heating the tube to the working temperature and passing oxygen through it. The temperature is about 700°C. in the portion containing copper oxide and considerably lower in the portion of the tube containing lead chromate. The blank portion of the tube is not heated at this stage unless the tube is new. The absorption tubes are weighed before and after a run of about half an hour when no alteration of weight should be found. If the tubes have increased in weight they are replaced until two successive sets of weighing are substantially identical. A small quantity of the powdered coal, about 0·15 gramme, is weighed into a porcelain combustion boat. This is placed in the blank portion of the combustion tube and the purifying train is again attached. The burners in this portion of the tube are at this stage not lighted. After the coal has been introduced, the end burner nearest the puri-

fying train is lighted causing a current of hot oxygen to pass over the coal. The other burners are subsequently gradually opened so that combustion of the coal goes on progressively. Finally, the tiles over this portion, which at first were open, are closed and the apparatus allowed to remain in this condition until about 15 minutes after the combustion is completed. The absorption tubes are then detached, cooled and weighed. The residue in the boat gives the weight of the ash. In this determination the carbon is partly burned directly in the oxygen and is partly oxidised in the layer of copper oxide which deals with any carbonaceous fumes given off by the coal. The function of the lead chromate is to absorb sulphur compounds, which would otherwise be retained in the caustic potash and weighed as carbon dioxide.

Ash.

It is a matter of interest in connection with the point previously mentioned regarding the arbitrary nature of the ash content of the coal, as determined by proximate analysis, that the ash given in the proximate analysis and the ash given under entirely different conditions in the ultimate analysis are generally appreciably different.

Nitrogen.

For the determination of nitrogen, one gramme of coal, 10 grammes of potassium sulphate, 0·5 gramme of copper sulphate and 30 c.cs. of concentrated sulphuric acid are heated in a Kjeldahl flask. The coal is thus decomposed and the nitrogen in it converted into ammonia. When decomposition is complete the contents of the flask are diluted with water and transferred to a 1,000 c.c. flask. About 100 cubic centimetres of a 50 per cent. solution of caustic soda are added and the contents of the flask distilled. The vapours given off pass through a trap to prevent liquid being carried over and then to a vertical condenser. The lower end of the condenser dips into 25 c.cs. of $\frac{N}{10}$ sulphuric acid. Ammonia, set free by the action of caustic soda, distills and is absorbed by the sulphuric acid. At the end of the distillation the sulphuric acid is titrated with $\frac{N}{10}$ caustic soda solution in order to determine the amount of acid remaining and hence that absorbed by the ammonia.

Sulphur.

For the determination of total sulphur, one gramme of coal is mixed with 5 grammes of Eschka's mixture, consisting of two parts of magnesia and one part of sodium carbonate. The mixture is placed in a 30 c.c. platinum crucible and one gramme of Eschka's mixture spread over

the top. The crucible is supported in a silica plate having a circular hole cut in the centre. This is in order to avoid the absorption of sulphur from the gas flame. The crucible is then heated from the bottom with a bunsen-burner at first gently and then more strongly until the carbon has been burned out. The contents of the crucible are cooled and extracted with water. To the aqueous solution bromine water is added and then hydrochloric acid. The solution is then boiled and 25 c.cs. of a 10 per cent. solution of barium chloride are added. This precipitates barium sulphate in proportion to the sulphate present. A blank determination is necessary in this process to allow for sulphur present in the reagents. The sulphur thus obtained represents the total sulphur in the coal, whereas some of this is already accounted for in the ash. It is therefore necessary to determine the amount of sulphur contained in the ash and to subtract this from the total sulphur in order to obtain the volatile sulphur.

Sulphur can also be determined by igniting coal in a bomb calorimeter. The bomb is washed out and the washing treated generally in the manner just explained. In the writer's experience, however, this method, although sometimes recommended without reservation, is entirely illegitimate with certain bombs which are lined with enamel containing sulphur. It is not of course possible to say that all enamel lined bombs are open to this objection, but it is wise to regard them with suspicion.

Oxygen.

There is no direct method of determination of oxygen. This amount is found by difference, *i.e.*, by deducting the sum of the other constituents from 100 per cent.

NEW FOSSIL LOCALITIES WITHIN THE PANCHET SERIES OF THE RANIGANJ COALFIELD. BY E. R. GEE, B.A., *Assistant Superintendent, Geological Survey of India.*

WITHIN the southern part of the Raniganj coalfield, Bengal and Bihar and Orissa, to the east of the Barakar river, rocks of the Panchet series crop out over wide areas. The series comprises a basal zone of khaki-green shales with hard calcareous bands, interbedded with medium-textured, yellow, felspathic sandstones; these beds pass upwards into the upper Panchets, which include yellow-grey and grey, soft, micaceous sandstones, with dark-red and occasional light-coloured clays intercalated. The basal beds, now designated by Dr. C. S. Fox, the *Maitur stage*, are from 250 to 300 feet in thickness and rest with a slight unconformity on the Kumarpur fossil-wood sandstones [1] of the uppermost part of the Raniganj beds. Numerous plant remains are found in the uppermost horizons of the Raniganj beds.

Plant-fossils from Maitur.

In the case of the Panchet series of the Raniganj coalfield, however, only within this lower zone of khaki-green and yellow-coloured sediments, and at only one locality,—Maitur, near Asansol,—had identifiable plant-fossils been discovered, previous to the recent geological re-survey. This solitary find, on which the whole of the Panchet flora has been based, was made by Mr. W. T. Blanford in the course of his examination of the coalfield during the years 1858-60, and a description of the occurrence is included in his memoir on that area.[2] The name of the village of Maitur has, apparently, fallen into disuse and is not included in the more recent topographical maps. The locality at which the fossils were discovered by Blanford was within the lower Panchet outcrops of the Nonia river in the vicinity of the bend due east of Kumarpur (86° 56′ ; 23° 41′ 50″), that is to say, about half-a-mile northeast of the

[1] *Rec. Geol. Surv. Ind.*, Vol. LX, pt. 4, pp. 365-366, (1928).
[2] *Mem. Geol. Surv. Ind.*, Vol. III, pt. 1, pp. 129-130, (1865).

Asansol Inspection bungalow. These fossil-plants were later described by Dr. Feistmantel,[1] and include the following types :—

Schizoneura gondwanensis.
Pecopteris concinna.
Cyclopteris pachyrhachis.
Oleandridium.
Glossopteris indica.
Samaropsis.

In addition to these plant-fossils, Blanford discovered the remains of the entomostracean *Estheria* in these beds, and, within the higher Panchet strata exposed in the southern bank of the Damodar river just north of the village of Deoli (86° 53′ 15″ ; 23° 38′ 50″), a bone-bed was found, 'containing detached, and, frequently, rolled bones, vertebrae, and fragments of jaws with teeth.'[2] These vertebrate fossils have been described by Professor Huxley,[3] and include various Labyrinthodonts and Dicynodonts, indicative of a lower Triassic age.

The Deoli bone-bed.

It is very probable that, within recent years, the Nonia river has silted up considerably in the plant-fossil locality of Maitur, so that, in spite of a careful search by the late Rao Bahadur S. Sethu Rama Rau and myself, no additions to Blanford's collection were discovered.

During the early part of the field-season, 1928-29, however, during a somewhat hasty examination of the Panchet strata of the Raniganj field, to the south of the Damodar river, I was fortunate enough to find Panchet fossils at two localities. These included :—

The fossil localities of Alkusa and Kukhrakuri.

1. Plant fossils (Reg. No. K-25·140-144) in the southern bank of the Mosikadna *jor*, just south of the village of Alkusa, (86° 51′ 30″ ; 23° 38′ 45″).
2. Fish scales, etc., (Reg. No. K-25·133-140) just northeast of the large tank, situated 660 yards southeast of Kukhrakuri village, (86° 58′ 40″ ; 23° 36′ 55″).

The strata of the former locality include soft, micaceous, yellow-green shaly sandstones and shales of the basal Panchets, an horizon

[1] *Pal. Ind.*, Ser. XII, Vol. III, pp. 39-40.
[2] *Mem. Geol. Surv. Ind.*, Vol. III, pt. 1, p. 129, (1865).
[3] *Pal. Ind.*, Ser. IV, Vol. I, pt. 1.

similar to that of Maitur. On account of the nature of the matrix the leaf impressions are indistinct in detail, though they definitely include species of *Glossopteris*, (probably two species), and *Schizoneura.*

The Kukhrakuri locality includes strata of a slightly higher horizon than those of Alkusa, though still belonging to the green shale and sandstone stage of the lower Panchets. The fossils were found within a thin band of greasy, grey shale intercalated within these strata, and in addition to the above-mentioned fish-scales, etc., badly-preserved plant-fragments, partially carbonised, were discovered. On account of the possible importance of these fossils, in fixing the age of the Panchet beds, the specimens were forwarded to the British Museum (Natural History) for examination.

According to Dr. E. I. White the only identifiable specimens in the collection received in London belong to the Palæoniscid genus *Amblypterus*, fishes which lived in the lakes and rivers of Carboniferous and Permian times. Their occurrence in the basal Panchet (Maitur stage) gives these beds a strong Palæozoic aspect and suggests a Permo-Triassic age for the Panchet series. Their discovery and identification adds yet another piece of evidence in support of the official opinion that the Raniganj beds below are of Permian age. The floral relationship of the Raniganj and Panchet beds further justifies the inclusion of the Panchet strata in the Lower Gondwana division. Finally these factors—the Palæozoic aspect of these fish remains and the Damuda affinities of the plant remains —supply almost a final argument against a tripartite sub-division of the Gondwana system and confirm our conviction of the correctness of the two-fold classification recognised by the Geological Survey of India since 1879.

AN UNDESCRIBED SPECIES OF *Cyllene* FROM THE PEGU BEDS OF BURMA. BY B. B. GUPTA, F.G.S., *Assistant Superintendent, Geological Survey of India.* (With Plate 5.)

CYLLENE VREDENBURGI, n. sp.

(Pl. 5, figs. 1, 1*a*, 1*b*.)

Description.—Test small, elongate oval; whorls ornamented with axial ribs. Body whorl large. The axial ribs in the body whorl crossed by faint radial furrows, producing a somewhat cancellated appearance. The posterior portion of the body whorl is gradually sloping towards the suture. There are three spiral furrows in the slope, cutting the axial ribs, which are slightly wavy. Aperture oval. Outer lip oblique, with plications. Inner lip callous. Anterior columellar margin with six plications, placed almost at equal distances from one another. The distance between the second and third plications (counting from the posterior side) is slightly greater. The second and third plications are also thickened and slightly bent at their outer extremity.

Remarks.—The late Mr. Vredenburg recorded (*Rec. Geol. Surv. Ind.*, Vol. LV, p. 68) two species of *Cyllene* from the Pegu beds of Burma, of which one having collapsed only one, *C. pretiosa*, Vred., was figured (*Rec. Geol. Surv. Ind.*, Vol. LV, p. 69, Pl. 2, fig. 2). From the description of the destroyed specimen (*Rec. Geol. Surv. Ind.*, Vol. LV, p. 68, foot-note) it does not appear to be identical with the present species. I have compared it with *C. pretiosa*, Vred., from which it differs in ornamentation, which is much finer in *C. pretiosa*; the radial and transverse grooves in Vredenburg's species are almost of equal strength, while in the species here described, the transverse grooves are stronger than the radial ones. They differ also in the number of plications in the columellar margin and in their disposition—the number of plications in Vredenburg's species being eight, of equal strength and placed at equal distances from one another.

The shell bears some resemblance to *C. varians*, Cossm. from the Pliocene of Karikal (*Journ. de Conch.*, LI, 1903, pp. 134-136, pl. VI,

figs. 18-20). The Burmese species here described differs from it in that the slope on the posterior side of the body whorl of the Burmese species is gradually sloping towards the suture, while in the Karikal species there is a sudden descent, whereby something like an angle is formed between the slope and the rest of the body whorl. The most posterior radial rib of the body whorl, *e.g.*, that next to the suture, in the Burmese species, is also slightly raised above the suture line, which does not seem to be the case in Cossmann's species. The number of spiral furrows in the slope in the Burmese species is less than those in the species from Karikal.

The specimen is incomplete, wanting its apical portion.

Locality.—The specimen was obtained from the stream half a mile above Myaukmigon.

Formation.—Pegu beds.

Collector.—Mr. A. H. M. Barrington, Conservator of Forests. Hlaing Circle, Burma.

EXPLANATION OF PLATE.

FIG. 1.—*Cyllene vredenburgi*, n. sp. Nat. size.
FIGS. 1*a*, 1*b*.—*Cyllene vredenburgi*, n. sp. × 3.

TWO NEW SPECIES OF *Unio*. BY B. B. GUPTA, F.G.S., *Assistant Superintendent, Geological Survey of India*. (With Plate 5.)

IN recent years, there have been several notices of fossil Unionids from Burma, among which some ribbed varieties of Irrawaddian age have been described (*Rec. Geol. Surv. Ind.*, Vol. LI, pt. 4). During the field-season, 1927-28, I collected some from the Pegus. The shells are very fragile and it was with the greatest difficulty that I was able to collect some fit for description.

Simpson and Ortmann have recently revised the classification of the Unionids, basing their researches on the differences existing in the soft parts, more especially the marsupial apparatus of the shell. As the shape of the shell is not at all correlated with the natural divisions indicated by the structure of the soft parts, this system cannot with certainty be applied in the case of fossils.[1] I have, therefore, used the more comprehensive term '*Unio*' in preference to generic names like '*Nodularia*,' Con. or '*Indonaia*,' Prashad, which were instituted by their authors from a study of the soft parts of the animal. I must admit, however, that the external characters of the Pegu shells suggest their relationship with the recent genera mentioned above, especially with the genus '*Nodularia*,' Con. and more particularly with the species *N. crispata*, Gould.[2]

The shells under description are characterised by very strong ribs, which cover the whole of the disc or a greater part thereof. The ornamentation is more or less of a similar nature, and with the exception of one, almost all the shells appear to belong to the same

[1] Zittel—Text book of Palæontology, 2nd edition, (English) (1913), p. 454.

[2] In his paper 'Studies on the anatomy of Indian Mollusca' (*Rec. Ind. Mus.*, Vol. XV, p. 147), Dr. Baini Prashad remarks, 'It is to be expected that the structure of the animal in the other Indian species hitherto assigned to the genus "*Nodularia*" would be similar, and the genus "*Indonaia*" would therefore include all the species described by Preston (Fauna of British Indian Mollusca, pp. 135-146); consequently *N. crispata*, Gould, with which the Burmese shells appear to be related, is to be regarded as a species of "*Indonaia*," Prashad. It may be noted that several fossil species of *Unio* from India and Burma have been assigned to this genus. (Vide *Rec. Geol. Surv. Ind.*, Vols. LI, LV, LX).'

species. They were all collected from a clay bed in the Lawin *chaung*, 2 miles S. E. of Saingde (22° 31′ ; 94° 30′ app.).

Description of species.

UNIO EDWINI, n. sp.

(Pl. 5, figs. 2, 2*a*.

Shell ovato-subtrigonal, thick, inflated, rounded anteriorly, slightly elongated behind, with a narrow posterior wing. Umbos anteriorly situated, somewhat compressed. Base line gently curved up behind to meet the posterior ridge, which is fairly developed. The hinge is partially preserved in one otherwise incomplete specimen, which shows two pseudo-cardinals.

Shell boldly sculptured by coarse radial, rather closely-set, ribs running obliquely downwards from the posterior ridge and, before they reach the centre of the disc, they diverge upwards forming a V-shaped sculpture and bend downwards again and either make a simple gentle curve as they approach the anterior margin or break up into granulations exhibiting a zig-zag outline.

The radiating ribs do not cover the whole of the disc, but end a little above the ventral margin, where a few concentric lines are seen. The ribs, which are not of uniform thickness throughout, are seen to be traversed by fine concentric striae which likewise mark the concave grooves between those ribs. In some specimens ribs are seen to send off branches to anastomose with their neighbours.

Dimensions.—The figured specimen is 25 mm. long and 19 mm. high. A second specimen measures 27 mm. long and 21 mm. high.

Remarks.—The shell, which is named after Sir Edwin Pascoe, Director, Geological Survey of India, has some resemblance to *Indonaia glyptica*, Vred. and Prashad (*Rec. Geol. Surv. Ind.*, Vol. LI, p. 372) from the Irrawaddian formation of Burma. The Pegu shells are, however, smaller, and are relatively higher than the other. In *U. edwini*, the marks of ornamentation persist down to several layers of the shell, but in *I. glyptica* they do not so persist. *U. percorrugata*, Whittf. from the Laramie group (*Bull. Am. Mus. Nat. Hist.*, Vol. XIX, 1903, pl. XL, figs. 3 and 4) has somewhat similar sculpture, but they differ in details.

UNIO EDWINI, n. sp. var. 1.

(Pl. 5, figs. 3, 3*a*.)

The ornamentation of the shell referred to this variety differs from the type, in the V-sculpture ending about half way between the beak and the ventral margin. Here we see a slight concentric depression in the shell. A criss-cross ornamentation formed by anastomosing ribs is seen to extend from here to a little above the ventral margin where concentric lines are seen. The length and height of the figured specimen are 22 mm. and 17 mm. respectively. There is another specimen which measures 20 × 19. This is rather abnormal.

UNIO EDWINI, n. sp. var. 2.

(Pl. 5, figs. 4, 4*a*.)

In this variety the radiating ribs are stronger and not so numerous as in the type specimen. There is also a little difference in the disposition of the ribs. On following them from the posterior side, they are seen to run obliquely downwards towards the centre and then to pass upwards for some distance as in the type, but then they bend downwards for a brief space and then upwards again for some distance before they make the curve which approaches the anterior margin. The specimen measures 24 × 17 mm.

UNIO PILGRIMI, n. sp.

(Pl. 5, figs. 5, 5*a*.)

Description.—Shell small, rather elliptical, inflated, umbos anteriorly situated, somewhat compressed. Posterior ridge not well marked; rounded anteriorly. The whole of the disc is ornamented by zig-zag radial ribs covering almost the whole of the disc; near the ventral margin, the disc is ornamented with two or three concentric lines. The radial ribs and the concave furrows between them are marked with fine concentric striae. The shell is incomplete, measuring 19 × 14 mm.

Remarks.—It is to be distinguished from *U. edwini* not only by its shape, which is elliptical, but also by the radial zig-zag ornamentation. This shell is named after Dr. G. E. Pilgrim, Palæontologist, Geological Survey of India.

EXPLANATION OF PLATE.

FIG. 2. —*Unio edwini*, n. sp. (Type Specimen). Right valve. Nat. Size.
FIG. 2a.—*Unio edwini*, n. sp. (Type Specimen). Right valve. × 2.
FIG. 3. —*Unio edwini*, n. sp. var. 1. Right valve. Nat. size.
FIG. 3a.—*Unio edwini*, n. sp. var. 1. Right valve. × 2.
FIG. 4. —*Unio edwini*, n. sp. var. 2. Left valve (with right valve attached). Nat. size.
FIG. 4a.—*Unio edwini*, n. sp. var. 2. Left valve (with right valve attached). × 2.
FIG. 5. —*Unio pilgrimi*, n. sp. (Type specimen). Nat. size.
FIG. 5a.—*Unio pilgrimi*, n. sp. (Type specimen). × 2.
FIG. 6. —A broken specimen of *U. edwini* showing pseudo-cardinals. × 3.
FIG. 7. —*U. edwini*, n. sp. showing anastomosing branches of ribs. × 3.
FIG. 8. —*U. edwini*, n. sp. showing the umbones and the ligament. Nat. size.
FIG. 9. —*U. edwini*, another specimen, showing the umbones and the ligament (partly). Nat. size.

THE GLACIERS OF THE KARAKORAM AND NEIGHBOURHOOD. BY MAJOR KENNETH MASON, M. C., R.E., *Superintendent, Survey of India.* (With Plates 6 to 8.)

CONTENTS.

INTRODUCTION.

SYSTEMATIC observations of the snouts of glaciers in the Himalaya were first carried out by members of the Geological Survey of India in the year 1906. Marks were cut deeply into the rocks adjacent to the snouts of certain glaciers, and observations recorded concerning their recent movements. Some of these snouts have been since re-visited by travellers interested in the questions involved, and others have been seen and marked. But even now there is but little evidence upon which to draw conclusions, for travellers do not yet realize the importance of exact observations. It is hoped by the publication of these notes to draw attention to the more important questions, and to encourage future travellers to record more carefully the observations they may make.

Of the 34 glaciers noted on in the following pages, four were observed by the late Sir Henry Hayden in 1906. They are the Hispar, the Yengutsa, the Minapin and the Hasanabad; all of these are in the Hunza-Nagar region. Others examined about the same time, but not falling in the present investigation, are the Hinarche and Barche of Bagrot; the Sonapani, the Bara Shigri and the Perad of Lahul; and the Pindari, the Milam, the Shankalpa and the Poting of Kumaun. Since Hayden's results were published in *Records of the Geological Survey of India*, Vol. 35, travellers' observations have been recorded in various publications, and are not always easy to find; while some, notably those of Captain Bridges in the Shingshal valley, have been buried in official files. It is possible that others may still lie waiting to be exhumed from some private or Government necropolis.

A most important contribution to the subject has recently been made by Mr. Ph. C. Visser, as the result of his two Karakoram expeditions of 1922 and 1925. In a detailed paper in *Zeitschrift für Gletscherkunde*, Vol. XVI, pts. 3/4, 1928, he has given his observations of no fewer than 18 of the glaciers described in the following pages. As far as his own explorations were concerned, he has studied the factors bearing on glacier movement, and drawn his conclusions. I am indebted to Dr. W. A. K. Christie, of the Geological Survey of India, for his admirable translation of the more important parts of this valuable paper, which I have used freely in my compilation of these notes. It is to be hoped that Mr. Visser will have as important a contribution to make on Karakoram glaciology after his present expedition (1929).

The *snout* of a glacier, or its lower extremity, is that point where the melting caused by the increased temperature of lower altitudes balances the supply of ice from above. It will therefore be readily understood that the position of a glacier snout is poised, as it were, between these two main factors, and that the slightest change in either may upset the balance and lead to a variation of the level of the snout from time to time.

The movements of glacier snouts.

Secular variation.

If local characteristics, peculiar to each glacier, such as the size and nature of the névé region, the slope of the bed, the width and direction of the outlet valley, could be ignored, we should expect all glaciers in a particular region under the same climatic conditions to reach down to the same altitude above sea-level. If then the supply of ice from above remains the same, and a general increase of temperature occurs, melting and waste of the ice will increase, the glaciers will degenerate and their snouts will recede equally. If the temperature falls, the snouts will advance equally. If a definite change of climate occurs, and an equal increase or decrease of snowfall results in the area of each glacier, then all will ultimately advance or retreat to the same extent. Such *secular* changes in temperature or climate lead to what are known as *secular* movements of the snout. They will be distributed over long cycles of time.

Conversely, if we consider these two factors alone, and if we can measure the secular movements of glacier snouts, we should have a measure of secular climatic change, either of snowfall, or of temperature, or of both. We should be able to decide whether there is a definite recession of the snow-line ; whether the climate is getting warmer or colder ; whether the region is becoming more or becoming less habitable by man. By comparing our conclusions with those obtained in other parts of the world, we might discover whether the secular change is world-wide, or merely regional, and whether we are moving nearer to another ice-age, or still receding from the last. In this connection it must be remembered that scientists are not yet convinced that the evidence of a uniform Eurasian Ice-age is conclusive.

Were the problem as simple as this, we could regard glaciers as Nature's secular barometers, laid on the bosom of the earth, to warn men of the future. Except at the time of change from one to the other, all glaciers of a region should be advancing secularly or retreating secularly at the same time.

Unfortunately there are many complications. Besides the secular change in climate, there may be periodic change, due to short periods of climatic variation. These short periods may be related to the Brückner cycles. But the observations at the snout can only indicate such cycles and not the actual time of climatic variation, for no two glaciers are identical, and there is no standard by which we may compare them. The ratios of their regions of supply to their regions of waste vary between wide limits. Some glaciers, lying in broad open valleys with a north-south direction, are exposed for long periods of the year to a hot sun; others, enclosed in narrow valleys with steep walls, may never see it. Some may be subject to thaw by rain in their lower reaches in summer-time; others may be in an arid region where there is much evaporation and almost no rainfall. Some may lie on steep, hard, rocky beds; others on soft ground at a gentle slope. Some may be enclosed by great slopes of névé, or have at their head great basins above the snow-line, which form an unending reservoir of ice; others may be enclosed by rocky walls, which supply little but rock. Between all these extremes there is every combination of factor and circumstance, so that a small change of climate may cause marked fluctuations in the snout, smothering all secular movement, and vitiating all secular observations.

Periodic variation.

Not only are there these complicated physical factors affecting the glacier itself, but there are so many complications of climate, that it is surprising that the snout movement of any glacier should reveal the periodicities or phases of climatic variation until many centuries of observation become available. The amplitude of all the different periods of climatic variation, of which the existence and significance have been apparently proved, are small in comparison with the irregular or haphazard variations in weather. By compounding all the known and apparently significant periods of past climate, as is done for tidal prediction, we do not, unfortunately, arrive at a forecast of coming changes, because the irregular variations are too powerful.

These complicated factors affect the periodic movements of the snouts of glaciers in a very marked manner. Ultimately the movements are due to climate and snowfall, but the factors are so varied that the snout movements appear to be peculiar to each particular glacier. There may be little resemblance between the periodic movement in neighbouring glaciers of a range, even if

they have the same exposure; sometimes there is no similarity between the periodic movements in two branches of the same compound glacier; and occasionally one side of a glacier tongue may be advancing while the other retreats. Such anomalies are generally the result of compound glaciers or of important tributaries joining the main glacier near the snout. Yet in spite of all these factors, the actual periodicity of single glaciers may be *approximately* the same, provided it is not obscured by seasonal or accidental causes, even though they may be out of step.

Ablation is the term used to denote the superficial waste of a glacier by surface melting or evaporation, which eventually determines the position of the snout. Ablation occurs mainly by the agency of the following factors: (1) the direct rays of the sun, (2) radiation from barren valley walls, (3) erosion by running water, (4) conduction of heat through moraine material, (5) contact of warm air and radiation from moist air and low clouds, (6) evaporation, and (7) rain. The greater the surface exposed to these factors in the area below the snow-line, especially during the summer, the greater will be the wastage and the greater the altitude of the snout above sea-level.

Seasonal variation.

The region above the snow-line on any glacier is its region of supply; below the snow-line is the region of waste. Yet during the colder months of the year on most glaciers there is constant supply and little waste taking place right down to the snout. In the depths of winter all precipitation feeds the glacier as snow, the sun has little power, radiation and conduction are consequently negligible, rain and running water non-existent. We may thus expect a *seasonal* advance in winter, a *seasonal* retreat in summer. The summer retreat is usually accompanied by a flattening and temporary degeneration of the snout.

In the winter and spring we should expect a steep-fronted clean glacier, the white ice conquering the englacial moraine; in summer and autumn the sun and rain flatten the snout by melting, and englacial moraine comes to the surface. These signs are normal seasonal signs; they are often wrongly adduced as evidence of secular or periodic movement. In reality they are normal if the secular and periodic movement are *nil*. It is only when a glacier in summer shows a steep-fronted end, or in winter a flattened one that we can use this evidence for periodic or secular advance or retreat.

There is a further complication which may be termed *accidental*. The effect of avalanches is partly periodic, partly seasonal and partly accidental. A glacier may suddenly overcome an obstacle in its path. An earthquake may cause a considerable accidental advance, and a 'dead' end may be detached from the living ice. On steep hanging glaciers large masses may be detached from no apparent cause. Such dead ends must for a time be below the point of balance between supply and waste, and must gradually melt and disappear. These accidental advances will entirely vitiate all observations for secular, periodic or seasonal movement.

Accidental variation.

Thus we may look on glaciers as barometers for secular movement, and as thermometers for periodic, seasonal and accidental fluctuation, and, as may be imagined, the problem of resolving glacier movement into its various components, secular, periodic, seasonal and accidental, is extremely complicated. The more glaciers we can examine in a given area, the more likely we are to form a correct conclusion. Every glacier in a region should be studied, for there are few that will not teach us something. Their peculiarities should be studied before we can even say which are likely to give us the most information, and all observations should be made with such care that no doubt exists concerning their accuracy. To be absolutely certain, observations should be made against marks cut in rock *in situ*, as advocated by Sir Henry Hayden.

It has been stated that secular movement is important from the point of view of climatic change. Periodic movement is responsible for glacier blocks and sudden cataclysms due to bursting glacial dams. Seasonal and accidental changes are less disastrous except to those living in the immediate vicinity of the snout. Fortunately, we are already able to define approximately those glaciers in which secular and periodic movements are least likely to be smothered by each other and by other movements. I believe that secular movements preponderate and periodic, seasonal and accidental movements are least effective in large longitudinal valley glaciers, with a small ratio of supply area to waste area; in glaciers which flow in broad straight valleys with a general east-west direction; where the slope of the glacier-bed is gentle and even; where the tributary glaciers are open, exposed and with gentle even beds, and neither they nor the lower reaches of the main glacier

Conditions favouring secular movement.

are subject to large avalanches; and where such tributary glaciers have small areas compared with the main glacier, and enter not too near the snout. These secular movements can then be measured when the snout itself is not subject to erosion by its own or another stream.

Glaciers showing secular movements.

Applying these theories to the thirty-four glaciers investigated in this paper, and shown on the accompanying charts, which illustrate the positions of their snouts as far as we know them, the following most generally bear out the conditions of secular movement. None of course are perfect, but I believe in most cases the movement, if any, is mainly secular. Without reference to their observed movement, I placed them according to the above conditions in their order of suitability:—

(1) The Hispar (No. 1).
(2) The Baltoro (No. 22).
(3) The Siachen (No. 23).
(4) The Rimo (No. 28).
(5) The Virjerab (No. 15).
(6) The Pasu (No. 7).
(7) The Biafo (No. 20).
(8) The Batura (No. 8).
(9) The Mamostong (No. 24).

Observations are as yet very scanty and incomplete and it must be remembered that those of last century were rarely made with any scientific motive. Nevertheless, as far as we can say at present, all of these are either stationary or in very slight secular retreat, except the Biafo (*see chart*). This glacier is peculiar; its basin is complicated by a vast accumulation of névé in the snow-lake at its head, which gives a ratio of supply to waste of 3 : 4. This, as will be seen below, is, I believe, one of the main factors of periodic fluctuation, for even comparatively small periodic changes in the supply area are magnified to such an extent that they show marked changes at the snout. There are minor factors which also make for periodic fluctuation in the Biafo glacier; its general direction is south-east and its south-western wall is broken.

The Hispar and Baltoro glaciers are to my mind as nearly perfect for secular observation as we are likely to find anywhere, in spite of the entry of large tributary glaciers not far from the snout. The

Siachen flows too much in a north-south direction, and its snout may be subject to a variable seasonal factor due to rain and radiation, and to periodic variation from radiation from the barren rock walls on to the crevassed broken surface of the lower reach. The Rimo is, I believe, mainly transverse, but has a low gentle fall; it also is complicated by being markedly compound, two large branches meeting near the snout; nevertheless it seems to be fairly steady and to show slight secular retreat. The Virjerab must, from Visser's description, be subject to periodic and seasonal variation, due to irregular supply, to the intense sun heat, to radiation and to conduction through the mass of moraine and debris that covers the ice completely for a long distance from the snout; it is most important, in glaciers of this description and liable to great seasonal change, to note the month and date of observation. Yet the ratio of supply area to waste area is extremely low, and this condition seems to magnify its secular retreat. The slope of the Pasu glacier is steep for a longitudinal glacier, and periodic movement is therefore magnified; observations have been unfortunate on this glacier and the early ones are unreliable; the condition of the moraines seems to indicate periodicity, but no signs of advance have been noted recently; the ratio of supply area to melting area is very low, the glacier being mainly fed by avalanches, and it may be that the retreat now observed is truly secular and not periodic. The Batura terminates in the Hunza river, which erodes the snout considerably, and all movement is hidden; but there are signs of decrease in volume. About the Mamostong we have insufficient data. None of these glaciers are perfect for our purpose, but most of them give an indication of secular retreat.

Conditions favouring periodicity.

The conditions favouring marked periodic change are in some respects rather the reverse of secular ones, Periodic change may be expected on transverse glaciers with large ratios of supply to waste areas; where the gradient is steep and the outlet valley narrow; where there are no large tributary glaciers entering the lower reaches of the main glacier; where the melting area is least affected by variable sun or radiation; and where winter and summer conditions are as nearly uniform as possible. We are, as it were, trying to measure the high and low tides of the glacier, and do not wish them to be affected by storms. With compound glaciers we may get a compound periodicity, whose departure from true periodicity

depends on the relative sizes, aspects, and slopes of the component glaciers, and the proximity of their junction to the snout.

Of the 34 glaciers investigated below, I believe that periodic movement can be observed in ten, but data are too scanty as yet for us to define the periodicity, except perhaps in four. The Minapin, the Kichik Kumdan, and the Aktash seem to me to have periodicities of 48, 45 and 55 years approximately, the observations of the last being however barely sufficient to warrant this estimate. The Chong Kumdan is the one about which we have most information, extending over a century. It has a total period of about 90 years, according to our definite information; but it seems to me probable that there was a valley block between 1878 and 1886 and possibly one or two floods (*see* chart)[1]; if this was so, its periodicity would be about 45 years.

I place the ten glaciers from which some periodicity seems to be traceable in the following order of importance:—

(1) Minapin (No. 4).
(2) Chong Kumdan (No. 29).
(3) Kichik Kumdan (No. 30).
(4) Aktash (No. 31).
(5) Biafo (No. 20).
(6) Lungmo-chhe 'A' (No. 33).
(7) Sasaini (No. 6).
(8) Pasu (No. 7).
(9) Malangutti Yaz (No. 12).
(10) Yazghil (No. 13).

The last two, however, advance across the Shingshal during the block and flood periods of the Khurdopin, and therefore are certain to be subject to accidental movements due to variable river erosion.

Of the remainder, either the observations are at present too scanty, their conditions not yet well enough known, or their movements are subject to such compound factors that nothing can be made of them. Many of them, however, have points of interest. I

[1] Since writing the above, I have been informed by the Chief Engineer of the North-West Frontier Province that the Indus gauge at Attock showed an abnormal flood during the middle of August, 1879, and another still higher one on 29th July, 1882. The second of these was five feet higher than that caused by the Shyok flood in 1929. I believe that these two floods were due to the bursting of the Chong Kumdan glacier dam during the last periodic advance of the ice. There is no record of any traveller having made his way up the Shyok valley during this time and no other explanation of these abnormal floods known. An examination of the chart shows how well they fit the 'periodicity curve'.

believe that earthquakes or other violent accidental factors, such as the sudden overcoming of some obstruction in the bed, have affected the Yengutsa (No. 2) and the Hasanabad (No. 5); possibly it was the same earthquake. Both the Virjerab (No. 15) and the Sasaini (No. 6) are probably a good deal affected by variable seasonal factors; the Malangutti, the Yazghil, the Khurdopin, the Kichik Kumdan, the Chong Kumdan, and the Batura are subject to erosion at the snouts. Some, such as the Hopar, are markedly compound. About the rest we have insufficient data to draw any conclusions whatever.

General conclusions.

From a study of all these observations and from an examination of the charts showing them, I conclude that the secular movement, if any, is one of extremely slow retreat, that is, the ice left by the last ice-age is still diminishing. The majority of those glaciers which show periodic movement seem to be in retreat, though a notable exception is the Chong Kumdan, which is at its maximum periodic advance (August 1929); but there is no reason why they should be 'in time' with one another. There are at present only two danger spots for glacial dams and consequent floods, *viz.*, the Shingshal valley and the upper Shyok. The dangerous glacier in the Shingshal is the Khurdopin, and it seems to require watching every year, or certainly at five year intervals. The most dangerous glacier in the upper Shyok is undoubtedly the Chong Kumdan. There seem to be danger periods lasting about eight years between safe periods of about thirty-seven years; during which eight years the glacier may burst and reform again. I do not believe that anything can be done to prevent these blocks and bursts, for the block can reform again during these eight years of advance.[1]

Arrangement of glacier observations.

The glaciers under consideration have been arranged for convenience in two main groups, Hunza-Nagar, and Baltistan-Ladakh. The former are reached most easily *viâ* Gilgit, the latter by either Skardu or Leh. These two groups have been sub-divided into two sub-groups, south and north of the main line of the great Karakoram peaks, and these sub-groups have been again divided into

[1] After the time of maximum periodic advance, periodic retreat appears to me to set in gradually, and may be counter-balanced at first by seasonal winter advance. For this reason I believe that the Chong Kumdan glacier will again block the Shyok valley in the winter of 1929-30, and there may be another minor flood in 1931. See *Himalayan Journal*, Vol. II.

valley regions. At the head of each glacier is given its map reference, its type, length, height of snout above sea-level, and its average fall, approximately. I have not attempted to give the ratio of supply area to melting area, though this is a very important factor, for the simple reason that I do not believe we have yet sufficient data. A brief summary of my conclusions is given at the end of each glacier. Particular attention is invited to the charts which show graphically the observed movements of each snout; and a sketch map shows the situation and rough form of each glacier.

OBSERVATIONS.

PART I.—HUNZA-NAGAR.

(*a*) GLACIERS SOUTH OF THE MUZTAGH-KARAKORAM RANGE.

1. Hispar Glacier.

Sheet, 42 L; *Type*, Longitudinal; *Length*, 38 miles; *Height of Snout*, 10,500 feet approx.; *Fall*, generally uniform, 7,000 feet, average 181 feet per mile (3·5%).

The Hispar glacier is a typical longitudinal trough glacier, the fourth longest outside sub-Polar regions, with a low and generally even gradient, broken only in two places, namely, between 16,000 and 17,000 feet, and between 13,000 and 14,000 feet. It descends from a broad basin about 3 miles wide, at the head of which is a barely perceptible rise to the Hispar pass, 17,560 feet, leading to the Biafo glacier and the great 'snow-lake', with its vast accumulation of névé. It seems probable that this reservoir serves to supply both the Biafo and Hispar glaciers, the ice being forced over the Hispar pass by pressure. To a less extent it also probably feeds the Khurdopin and possibly the Virjerab glacier of the Shingshal in a similar way.

On the north side of the Hispar there is a marked ablation valley and great transverse tributary glaciers descend from above the snow-line in the recesses of the Muztagh-Karakoram, the peaks of which rise well above 24,000 feet. These tributaries force the ice of the main glacier away from the valley walls. On the south the tributaries are of less extent; and beyond the Haigatum glacier the valley is enclosed by a steep unindented wall. The main trunk

of the ice-stream does not appear to be subjected to an unusual number of avalanches, as are the basins of the northern branches.

The Hispar was first seen by Godwin Austen from the summit of the Nushik La, a pass at the head of the Haigatum tributary; but he did not descend to its surface. It was first traversed and surveyed by Conway in 1892. It was visited and its snout carefully measured and marked by Hayden in 1906; and it has since been observed again in 1908 and many of its tributaries surveyed by the Workmans, and in 1925 by the Vissers.

The following is a summary of recorded observations of the snout :—

1889. The end of the glacier is shown on a small-scale planetable sketch by Surveyor Ahmad Ali Khan, Survey of India, but the scale is too small for any deductions to be made.

1892. Conway writes: 'A quarter of an hour after leaving Hispar we reached and crossed a moraine, thus entering a basin (about a mile long by a quarter to three-quarters of a mile wide), from which the glacier had retired comparatively recently. Such a small oscillation is of no importance, so that practically the Hispar glacier may be considered to have been stationary during the historic period, for the cultivated Hispar fan has been deposited since the main retreat of the ice' (*Climbing in the Himalayas*, p. 331). The glacier was surveyed by Conway, and the snout is shown on his map about 2,250 yards from the centre of Hispar village (Map: *The Karakoram Himalayas*, scale 1 inch=2 miles, sheet 1, *R.G.S.*, 1894).

1906. Hayden in September, recorded that the glacier had retreated 'a few hundred yards from the 1892 position.' This he considered might be due to seasonal variation, but he adduced the evidence of a narrow terminal moraine to support comparatively recent secular retreat. Hayden set up cairns, marked the snout's position and surveyed it. He states that it was about 1½ miles (=2,640 yards) from Hispar village (*Records, Geological Survey of India*, Vol. 35, p. 133, with photographs and plan, scale 1 inch =800 feet).

1908. The Workmans write: 'Our topographers found the Geological Survey pyramids placed on both sides of the river at the tongue. They report the shrinkage in the end of the Hispar tongue as not exceeding 30 feet. By the end of August, however, they

noticed that the depth of the tongue was much reduced, many large blocks of ice having fallen down and been carried away by the sub-glacial stream.'[1] The Workmans marked in red a large erratic boulder on the right bank with the initials and date of their expedition, repeating the marking on the left bank (*Geographical Journal*, Vol. 35, p. 108).

1925. On Khan Sahib Afraz Gul Khan's planetable, scale 1 inch=2 miles, surveyed during the Visser expedition, the snout is shown about 2,600 yards from the middle of Hispar village, and Visser himself states that 'the snout, entirely covered with rubbish now, lies 2·4 km.' [2,630 yards] 'up the valley from the village of Hispar'. He also records that the ice-cave was further north than in 1906. 'About 80 to 100 metres in front of the snout was a small terminal moraine, apparently new' (*Zeitschrift für Gletscherkunde*, Bd. xvi, 1928, p. 213).

Conclusion.—If Conway really records a retreat of a mile, it is not easy to agree with him that such a retreat is of no importance for a longitudinal glacier of such magnitude and fed by such immense tributary ice-streams. The glacier itself has a very even bed for the greater part of its course. It is certain that of the two tributary glaciers nearest the snout, the Garumbar, a southern tributary, which on Conway's map of 1892 was shown (as the Charum glacier) nearly 1½ miles from the Hispar, had advanced and joined the latter by 1925; yet the Kunyang or Lak glacier, the westernmost of the northern tributaries, was reported in 1925 to have shrunk considerably in volume. The figures given above showing the distance from Hispar village are of course approximate, and there seems to have been practically no change since 1906.

The Hispar fulfils most of the conditions for a glacier in which secular movement at the snout should preponderate over periodic and other movements.

There certainly seems to be at present practically no seasonal or periodic fluctuation in the main trunk, while these fluctuations of the lowest tributaries are 'out of time' with each other and have no apparent effect. There are indications, however, noted both by Hayden and the Vissers, of shrinkage and secular retreat, in the main Hispar glacier. Future observations should be made with reference to Hayden's marks.

[1] Normal summer ablation.

2. Yengutsa Glacier.

Sheet, 42 L ; *Type*, Transverse ; *Length* and *fall*, unknown ; *Height of Snout*, 10,800 feet approximately.

This glacier has not been accurately surveyed, and we do not therefore know the nature of its basin. It is, however, undoubtedly transverse, and has a fairly steep fall. Its lower part was roughly sketched by Conway in 1892, and a plan of its snout made by Hayden in 1906. The latter marked its snout and these marks were re-observed by the Workmans two years afterwards.

1889. A reconnaissance planetable sketch by Surveyor Ahmad Ali Khan, Survey of India, dated August-September, 1889, (scale 1 inch=8 miles), shows the track between Darapu and Hispar villages as crossing the gorge a little over 1½ miles north of the snout of the glacier.

1892. Conway records that the path from Darapu to Hispar descended into a precipitous gorge. 'A deep nala ..... divides Darapu from Hispar. In its bowels some half a dozen mills find a footing. The path goes round by these and mounts to the fair fields of Hispar' (*Climbing in the Himalayas*, p. 325). Conway's map shows the snout of this glacier, which he calls the *Rungpa*, a little over 1½ miles from the path, that is, almost exactly in the same position as it was shown on Ahmad Ali's sketch in 1889 (Map : *The Karakoram Himalayas*, scale 1 inch=2 miles, sheet 1, *R.G.S.*, 1894).

1906. Hayden reports that between 1892 and 1906, and most probably in 1901, the glacier advanced two miles. He writes : 'Now the path, instead of descending, climbs arduously over a steep mass of black and slippery ice, the mills are gone, and their ruins hidden under the snout of the advancing glacier' (*Records, Geological Survey of India*, Vol. 35, p. 134, with photographs and plan, scale 1 inch=800 feet).

1908. The Workmans write : 'The Yengutsa tongue descends at present to within 2,952 feet [984 yards] of the Hispar river... As points of study for the Yengutsa, Dr. Calciati and Dr. Koncza took the same two pyramids marked in black G.S.I., adding in red the initials, *B.W.*, and the date of our expedition in 1908... The glacier remains about as in 1906, manifesting only a small decrease in thickness and length. They report a recession of 989 feet as measured carefully from the line of pyramids on either side' (*Geographical Journal*, Vol. 35, p. 107).

1925. Khan Sahib Afraz Gul Khan's map, scale 1 inch=2 miles, (Visser expedition), shows that the snout of this glacier had retreated approximately 1,000 yards since 1906, and that the path again crossed the gorge some distance north of the snout. The Vissers in their papers make no mention of this glacier.

Conclusion.—The sudden advance in 1901 is almost certainly accidental, and was probably caused by an earthquake or sudden relief from some obstruction. It is interesting in view of the advances of the Garumbar glacier to the east and the Minapin and Hopar (Barpu) glacier to the west. All these glaciers have probably fairly steep falls, with probably large névé fields, subject to heavy avalanches from the northern slopes of the Kailas-Karakoram range. The advance of tho Yengutsa is, however, much more rapid and unexpected than that of the others, and seems to bear a closer affinity to the advance of the Hasanabad glacier. Unless some periodicity is discovered at a later date, I believe that the rapid advance in 1901 was accidental. We cannot at present attempt to define the periodicity of this glacier, and any secular fluctuation is cloaked by the violent accidental movements.

3. Hopar (Barpu) Glacier.

Sheet 42 L ; *Type*, Transverse ; *Length* and *fall* unknown ; *Height of Snout*, 8,400 feet approximately.

The Barpu glacier is really a tributary glacier of the Hopar or Bualtar, sometimes impinging on the latter and sometimes clear of it. The upper reaches of both are not properly surveyed, and no observations prior to Conway's in 1892 are of any value.

1892. Conway's map shows the snout of the Hopar glacier about a quarter of a mile clear of the Hispar river, and a gap of three-quarters of a mile between the Barpu and the Hopar. No lake is shown in the intervening space (Map: *The Karakoram Himalayas*, scale 1 inch=2 miles, sheet 1, *R.G.S.*, 1894).

1925. Visser records that the Hopar glacier (which he calls the 'Barpu') now came over the Hispar river to the right wall of the Hispar valley, so that there might be danger of a damming of the river. It was reported to him that up to 1922 or 1923 the glacier had greatly advanced, but that since that time it had retreated (*Zeitschrift für Gletscherkunde*, Bd. xvi, p. 214).

Conclusion.—See notes at the end of the Yengutsa glacier. Owing to confusion of names there is a little doubt about these

observations. There is no evidence of a former block of the Hispar valley by the Hopar glacier, and it is unlikely that a river of the size of the Hispar would be unable to keep a channel clear past or under this glacier. It is not easy to see how, if the glacier was in 1925 against the right wall of the Hispar valley, and then retreating, there could be any immediate danger of a valley block. Owing to the compound nature of the lower reaches, it would be almost impossible to determine the various factors contributing to snout movements.

4. Minapin Glacier.

Sheet, 42 L; *Type*, Transverse; *Length* and *fall*, unknown; *Height of Snout*, 7,050 feet.

The Minapin glacier has never been surveyed except near its snout, and its present representation on maps is that which was shown on the first rough reconnaissance maps. Its snout was however accurately surveyed by Hayden in 1906, by me in 1913, and it was again carefully observed by Visser in 1925. We therefore have a fairly accurate knowledge of the movements of this snout during the last 20 years. As far as I know, this glacier now descends to a lower altitude than any other glacier in the whole Himalaya or Karakoram. This fact is almost certainly due to heavy avalanches from an icy cirque, to the lowness of the snow-line and to the narrow constricted valley of the lower reaches of the glacier.

1889. This glacier is shown first on a small reconnaissance sketch by Surveyor Ahmad Ali Khan, of the Survey of India, dated August-September, 1889, scale 1 inch=8 miles. Its snout appears on this to be roughly 3,000 yards from the crossing of the Minapin ravine, at the approximate site of the future bridge.

1892. Conway roughly sketched the position of the snout, which is shown on his map to be about 2,900 yards from the site of the bridge (Map: *The Karakoram Himalayas*, scale 1 inch=2 miles, sheet 1, *R.G.S.*, 1894).

1893. Surveyor Khan Sahib Abdul Gaffar showed on his planetable (scale 1 inch=2 miles) the snout of the glacier 1,700 yards from the bridge-site.

1906. Hayden in September, reported that the total retreat in historical times had been considerable, since five generations ago the glacier extended down to the bridge-site. The crystalline limestone rock immediately N.E. of the snout had been polished and

grooved by the ice. Hayden suggested that the glacier might be advancing temporarily, though steadily retreating over long periods of time. He carefully marked the walls of the valley near the snout, set up cairns, and photographed the snout from the bridge. Hayden's description with photographs and plan (scale 1 inch=500 feet) is in *Records, Geological Survey of India*, Vol. 35, p. 131.

1913. I found that the glacier had advanced 700 feet since 1906. It was, therefore, about 1,170 yards from the bridge. Some of Hayden's cairns and marks were covered by the advancing ice, the rest were re-painted, and fresh ones made to show the new position of the snout. A photograph, taken from exactly the same position E, at the bridge, as Hayden's photograph, and a survey of the snout made by me on the scale 1 inch=700 feet, together with a description of the marks, appears in *Records of the Survey of India*, Vol. 6, p. 49.

1925. In this year Visser found that the glacier could no longer be seen from the bridge. He writes: 'It was now 600 to 700 metres further back than in 1913 ....As far as the eye could reach, the end of the glacier had sunk to an insignificant narrow strip of ice, buried beneath rubbish. There was exposed an extraordinarily characteristic "U"-shaped trough valley, deeply cut, with here and there smoothly polished walls. The outer bank shows strong glacial erosion. The moraines appeared to have been washed away by water. The limestone rocks, which form a strong dividing wall of about 150 metres high between the lower part of the Minapin valley and the Hunza valley, are beautifully polished and show glacial striæ, not only on the Minapin side, but also on the Hunza side, which incontestably show that the glacier formerly tumbled over this rock-ridge into the Hunza valley' (*Zeitschrift für Gletscherkunde*, Bd. xvi, 1928, p. 215; sketch p. 215; plate 30).

The glacier snout was, therefore, at least 650 yards further back than its position in 1913 and must have been at least 1,820 yards from the bridge. It is, therefore, intermediate between its 1892 and 1893 position. The snout is shown on Visser's sketch very shrunken and attenuated.

1929. Todd, the Political Agent of Gilgit, visited the Minapin glacier on 17th April. He was unfortunately unable to find any marks set up by the Vissers and had not their sketch-map with him. From rough notes which he took, it seems probable that the attenuated end observed by the Vissers had melted away and that

the actual snout was perhaps 100 yards further back than in 1925. Todd erected a large cairn level with the snout high up on the right bank. The inhabitants of Minapin village reported little change during the previous four years.

Conclusion.—The observations prior to 1906 must be accepted with reserve, since these early reconnaissances were very hurried. They do, however, indicate a slow but steady periodic advance between 1889 and 1892, when a rapid advance of about 1,200 yards seems to have taken place. In 1906 the snout had advanced a further distance of 300 yards, that is, the average annual advance between 1893 and 1906 was 23 yards as against about 33 yards for the period 1889-1892. The glacier must have been still advancing in 1906, as suggested by Hayden, its average annual rate being approximately 33 yards. It is probable that it was nearly at its maximum advance in 1913. It is interesting to record that during the period 1893 to 1906, the glacier snout was advancing through a valley with two right-angled bends in it, the ice being arrested by the limestone dividing wall and forced over and round it. Were it not for this obstruction, it is probable that the snout would have advanced more evenly and rapidly. Retreat seems to have begun in 1913, or soon afterwards, and the present condition of the tongue shows great degeneration. If reliance can be placed on the early observations, and they seem to fit in with the later ones, I suggest that the Minapin has a rough total periodicity of about 48 years, 24 of advance and 24 of retreat. There seem also to be general indications of secular retreat, but these are smothered at present by periodic movement.

5. Hasanabad Glacier.

Sheet, 42 L; *Type*, Transverse; *Length* and *fall*, unknown, *Height of Snout*, 7,290 feet.

The basin of this glacier has never been surveyed; its extent and nature are not yet known. This is regrettable, for it has the reputation of having undergone greater fluctuations than any other glacier in the world. The first to call attention to these movements was Dr. Arthur Neve in 1895, but it was not till Hayden visited the snout in 1906 and erected cairns and marked it, that we can be certain of the observations. Next to the Minapin, its snout descends lower than that of any glacier in the Karakoram or Himalaya, the reasons being similar in both cases.

1889. Surveyor Ahmad Ali Khan on his planetable, dated August-September, 1889, scale 1 inch=8 miles, shows the snout of this glacier approximately 6 miles from the road-crossing of the Hasanabad ravine.

1892. Conway's map shows the Hasanabad *nala* dotted. The snout is shown roughly 8 miles from the road-crossing, but it does not appear to have been visited, and the snout may have been entered from hearsay (Map: *The Karakoram Himalayas*, scale 1 inch=2 miles, sheet 1, *R.G.S.*, 1894).

1893. Khan Sahib Abdul Gaffar's planetable sketch, scale 1 inch=2 miles, shows the snout only 3,750 yards, or a little over 2 miles from the road-crossing. The first edition of the Survey of India Transfrontier Sheet No. 2 S.E., dated 1896, shows the snout as on Abdul Gaffar's planetable.

1895. Dr. Arthur Neve learned from a native that the ice had advanced 2 miles that year and from 4 to 5 miles the previous year. This must, it seems to me, refer to advances in 1892 and 1893, but even so it is not easy to reconcile these advances with the movements in 1903 as reported to Hayden in 1906 (*see* below).

1903. Sir Henry Hayden was told in 1906 that the glacier had suddenly advanced a distance variously estimated at from 6 miles to a day's march, during 2½ months (*Records, Geological Survey of India*, Vol. 35, p. 135).

1906. Hayden reported the snout to have been stationary since 1903. He painted marks in line with the snout (*Records, Geological Survey of India*, Vol. 35, p. 135, with photographs and plan, scale 1 inch=400 feet).

1908. Workman reported the snout to be in the same position as in 1906 (*The Call of the Snowy Hispar*, p. 25).

1913. Hayden's marks near the snout were repainted and photographed by me. The snout was in exactly the same position as in 1906. It was then about 2,000 yards from the bridge over the Hasanabad ravine (*Records of the Survey of India*, Vol. 6, p. 49).

1925. Visser examined this snout and shows a photograph in the *Geographical Journal*, Vol. 68, p. 460. By comparing his photographs with those of Hayden, Visser concluded that the volume of ice in the glacier had decreased considerably, while its length had remained the same. He reports that one portion of the snout had been cut off by the stream, and now formed 'dead' ice (*Zeitschrift für Gletscherkunde*, Bd. xvi, 1928, p. 216).

1929. Todd, Political Agent at Gilgit, visited the glacier on 18th April. He reports that its end was hidden under debris and that the stream issued from a dirty ice-cave about 400 yards up-stream of the line joining Hayden's marks, and 'about 1½ miles' from the bridge. He also reports a terminal moraine standing up in the river-bed in line with Hayden's marks. The snout at the time of Todd's visit was level with the mouth of the small *nala* coming in on the right bank. The local people reported that the glacier was shrinking year by year (*private letter*).

Conclusion.—The Wazir of Hunza told Hayden that the Hasanabad glacier occupied its 1906 position many years before, and that it had subsequently retreated rapidly. But it is hardly conceivable that it could advance nearly 6 miles in 1892/3, and then in the following ten years waste away for the same distance, in order to be ready for another 6-mile advance in 1903. If this were so, we would expect a similar wastage since 1903, whereas the position of the snout remained practically stationary in its position of maximum advance for over twenty years, though during the latter part of this period it wasted considerably.

Since Neve's hearsay evidence agrees approximately with the evidence on Abdul Gaffar's planetable, it seems reasonable to suppose that in 1895 the glacier was approximately 2 miles from the river-crossing; that between that time and 1903 the end shrunk and retreated perhaps a mile; and that it advanced again in 1903 perhaps a mile or so to its position of 2,000 yards from the bridge, which it maintained till 1925.

There were no signs of shrinkage in volume recorded in 1908 or 1913, but it was very marked in 1925. The glacier is now, 1929, definitely retreating and it will be very interesting to see if it retires to its position of the early 'nineties.

The upper basin of the glacier is probably subject to heavy avalanches. The trunk is almost certainly confined and lying on a steep bed. The valley through which it emerges is narrow. Yet even so, I believe that these violent movements must be treated as 'accidental', and caused either by earthquakes or by the overcoming of some obstruction in the bed. This glacier may be likened to a clinical thermometer with the bulb laid in the mountains. Its violent accidental fluctuations at the end of the narrow valley record its eccentricities in the same way as the mercury registers the fevers of a sick man. Secular or even truly periodic variations on

such a glacier as this are entirely obliterated by accidental movements.

Further observations, annual if possible, are required of the snout of this glacier. The next year of maximum retreat should be between 1935 and 1940, after which I believe it will advance.

(b) GLACIERS NORTH OF THE MUZTAGH-KARAKORAM.

The glaciers north of the Muztagh-Karakoram range will be dealt with in three regions, *viz.*: (i) those which drain directly into the Hunza river; (ii) those which drain directly into the Shingshal tributary of the Hunza river; and (iii) small miscellaneous glaciers in the Khunjerab-Ghujerab region.

(b) (i) GLACIERS DRAINING DIRECTLY INTO THE HUNZA RIVER.

6. Sasaini or Ghulkin Glacier.

Sheet, 42 L; *Type*, mainly transverse; *Length*, 11 miles approximately; *Height of Snout*, 8,000 feet approximately; *Fall*, 5,000 feet in first 3 miles (?) (31% approx.), 6,000 feet in the last 8 miles (?) (14%).

The Ghulkin glacier has never been accurately surveyed, its upper basin is unknown, and the figures of the fall given above are very rough. The snout also is unsuitable for accurate measurement, for it varies laterally year by year.

1885. Woodthorpe carried a route traverse past the snout. His map shows the end of the ice approximately 800 yards from the *left* bank of the Hunza river. In his *Routes* he describes the glacier as 'a few hundred yards west of the road' (*The Gilgit-Chitral Mission, 1885-86*, p. 135).

1891. On December 27th, after the Hunza campaign, E. F. Knight passed up the Hunza valley below the snout of this glacier (*Where Three Empires Meet*, p. 493).

1907. In June, Price-Wood passed up the valley below the glacier. He records that it extended 'right down to within a couple of hundred yards or less from the Hunza river' (*Travel and Sport in Turkestan*, p. 24).

1913. In May, I found the snout to be 300 yards from the *left* bank of the Hunza river. The ground was littered with massive

blocks of black ice, much intermingled with debris. There were several moraines, both lateral and terminal. The glacier appeared to have joined the main valley at one time further north. Local inhabitants reported that this glacier had never been known to block the main valley, but that at that time it was slowly advancing, and that its snout varied laterally each year. From the moraines and 'dead ice' at the snout, much of which had disappeared by August, I considered that the glacier had passed its position of maximum periodic advance, and had actually begun to retreat (*Records of the Survey of India*, Vol. 6, p. 49).

1922. On 27th June, Skrine was forced to cross the glacier on his way up the Hunza valley, but only because the streams issuing from it were unfordable (*Chinese Central Asia*, p. 30; and *private letter*).

1924. In October, Skrine skirted round the snout, crossing seven or eight streams. 'There was then a space of at least half a mile between the snout on our right (west) and the river' (*private letter*).[1]

1925. The Vissers passed the snout, but in their writings make no comment. Khan Sahib Afraz Gul Khan's map, however, shows the snout about 1,000 yards from the *left* bank of the Hunza river. It therefore appears to have retreated since 1913, and to be slightly further back than in 1885.

Conclusion.—These movements are seasonal or periodic. As yet there is little evidence of secular movement, though the snout in 1925 was further in retreat than recorded previously. Observations are, however, very scanty and insufficient. There has been no recorded blocking of the Hunza river, and there seems to be no danger of a block. This glacier is not suitable for accurate observation.

7. Pasu Glacier.

Sheet, 42 L; *Type*, mainly longitudinal; *Length*, 15 miles; *Height of Snout*, 8,000 feet approximately; *Fall* 3,000 feet in first 3 miles (*1,000 feet* per mile, *19%*), *6,000* feet in *last twelve* miles (*500* feet per mile, *9·5%*).

The Pasu glacier was not properly explored until the Visser expedition of 1925, but we have a certain amount of information about its snout. It has no important side tributaries and no com-

[1] In his book Skrine records that in October the *glacier was easier to cross than in 1922. Tihs statement has subsequently been corrected in a private letter as above.*

plicated system of névé feeders. It is reported by the Vissers to be fed for the most part by avalanches and falls from steep hanging glaciers. The ice-stream descends from the névé region in a beautiful cascade. From below this cascade the fall appears to be fairly even.

Beside the left bank with southern exposure, there stretched, in 1925, from about a height of 14,200 feet, an ablation valley with rich vegetation, almost to the Hunza valley.

1885. Woodthorpe carried a route traverse past the snout. The map prepared in 1894, from this traverse, shows the snout incorrectly reaching the right bank of the Hunza river. Both the original survey and Woodthorpe's report show the main road descending into the Pasu stream, some distance from the Hunza river, and the original survey shows the glacier one mile from the river. Surgeon Giles of the Mission writes: 'The Pasu glacier at present stops some 3 miles short of the Hunza river' (*The Gilgit-Chitral Mission, 1885-86*, pp. 136, 161). A detailed description of the country between the Sasaini and Pasu glaciers is given with an interesting photograph of the Pasu glacier.

1891. E. F. Knight, after the Hunza campaign, passed up the Hunza valley below this glacier on December 27th (*Where Three Empires Meet*, p. 493).

1907. In June, Price-Wood records that the Pasu glacier was about 1½ miles from the Hunza river (*Travel and Sport in Turkestan*, p. 24).

1909. Etherton crossed the moraine of the glacier. Beyond this fact, his observations are of no value, and he gives no evidence in support of his assertion that the glacier is steadily advancing (*Across the Roof of the World*, p. 49).

1913. I found a series of dead lateral moraines near the snout indicating periodicity in the retreat of this glacier. The snout was approximately in line with the cliffs to its north, which are some 1,200 yards from the river. There were no terminal moraines, and I concluded that the glacier had retreated too fast for them to form. In August the cliffs north of the glacier were marked, and a rough survey made of the position of the snout. Measurements, bearings, and a photograph with a sketch-map appear in *Records of the Survey of India*, Vol. 6, pp. 17, 50, 51.

1922. Skrine 'skirted round the foot of the glacier' in June, on his way up the valley (*Chinese Central Asia*, p. 30).

1925. Khan Sahib Afraz Gul Khan, when with the Visser expedition, surveyed the whole of the Pasu glacier. His map shows the snout 1,450 yards from the river-bank. Visser himself writes: 'I first examined the exact position of the snout, which, although it still reached the Hunza valley, showed signs of retreating' (*Among the Karakoram Glaciers*, p. 41; photographs of the glacier, but not of its snout, appear on pp. 42, 44, and in the *Geographical Journal*, Vol. 68, p. 460). Visser also reported that the inhabitants of Pasu village were unable to record any great movements for a number of years. The tongue showed no evidence of an advance and the snout went almost imperceptibly into rubbish (*Zeitschrift für Gletscherkunde*, Bd. xvi, p. 202).[1]

Conclusion.—Observations and records of the Pasu glacier have been unfortunate. The discrepancy between Surgeon Giles' report and Woodthorpe's map is most regrettable. If Surgeon Giles is correct in stating that the glacier was then *three miles* from the Hunza river, and if Price-Wood's observations are reliable, the glacier must have advanced 1½ miles between 1885 and 1907. Woodthorpe, however, only shows it *one mile* from the river in 1885, and if this is correct, the movement must have been more complicated. The doubt exists, and it would be unsafe to base any deductions on either report. If we assume that when Visser alludes to Hayden's observations of 1907, he has made a mistake for my observations of 1913, it seems safe to assume that the glacier is now undergoing slight periodic retreat, which may have begun about 1910. There is no evidence of secular movement, and most certainly no danger of the glacier blocking the Hunza valley.

[1] In his paper in *Zeitschrift für Gletscherkunde*, Visser says: 'The Pasu is the glacier which in 1907 was visited by Sir Henry Hayden for the sole purpose of studying its movements. Sir Henry Hayden prepared a map of the Pasu glacier and took a photograph of the snout; he made marks on the banks to determine the exact position of the snout. Falls of rock and avalanches had however unfortunately obliterated the marks; but the map and photograph gave a sufficient number of recognizable points to make certain that the glacier had retreated somewhat since Hayden's visit.'

Visser seems to be mistaken, for a diligent search through the files and records of the Geological Survey of India discloses no information regarding an examination by Hayden of the Pasu glacier. Nor could any trace of the Pasu glacier be found among Hayden's glacier sketches or in the negative register among the photographs taken by Hayden on his 1906 trip. It is possible that Visser refers to my observations of 1913. The point is important, because in 1907 the glacier was, according to Price-Wood, 1½ miles from the river, and probably advancing, while in 1913 it was only 1,200 yards from the river and probably retreating. According to Khan Sahib Afraz Gul Khan, the glacier was 1,450 yards from the river in 1925. The Khan Sahib's map seems to be correct.

8. Batura Glacier.

Sheet, 42 L ; *Type*, longitudinal ; *Length*, 36 miles ; *Falls*, 2,000 feet in the first 2 miles (1,000 feet per mile, 19%) ; 5,000 feet in next 12 miles (417 feet per mile, 7·9%) ; 3,000 feet in last 22 miles (136 feet per mile, 2·5%) ; *Height of Snout* above sea level, 8,030 feet.

Except for the fact that the Batura was a very large glacier of probably over thirty miles, nothing was known of the body of this glacier beyond a mile or two from its snout until the Visser expedition of 1925. We now know that the Batura is made up of two main streams, which unite about 22 miles from the snout ; it is believed to be the sixth longest glacier outside sub-Polar regions. The southern and longer arm is formed by the union of three streams of névé. The longest of these streams, which lies furthest to the north, and which was explored by the Vissers, is shut in by steep walls of rock.

The great range along the right bank of the Batura forms an enormous wall about 20 miles long, practically nowhere lower than 20,000 feet, and culminating in two peaks over 25,000 feet. Visser gives the relative areas of névé and melting as 97 square kilometres and 185 square kilometres, so that the two portions are related to one another as approximately 1 : 2. The mountain wall is supported by projecting ridges, much as a church is supported by buttresses, and between these buttresses about 20 glaciers of varying size stream down in beautiful ice-falls to the great Batura glacier. Visser writes : 'Nowhere else have I heard such uninterrupted avalanches thunder as in this part of the Karakoram. This incessant roar provides the solution of the problem of how this long valley with its small névé-fields gets its fodder. We saw a further solution in the enormous blocks of ice and snow lying heaped up on the glacier, and also the indented tracks of dust avalanches which were everywhere visible on the ice-armoured walls.'

The left enclosing mountains of the Batura are not nearly so high. The snow covering is much smaller and only four insignificant tributaries feed the glacier. The fall of the glacier is extraordinarily small, only 2·5 per cent. for the last 22 miles, and throughout the whole length the evenness of its longitudinal profile is only broken at two points by ice-falls. Visser gives rough calculations of the maximum thickness of ice 39 kilometres from the snout, and puts it at from 510 to 670 metres.

A long ablation valley stretches along the left side of the glacier from above the junction of the two arms 22 miles from the snout and continues almost to the end of the glacier; but it actually finishes where the lower cascade begins and so it does not form an avenue of approach from the Hunza valley.

The snout generally projects into the Hunza river and so is much subject to erosion. The following are selections of observations made by various travellers.

1885. Woodthorpe carried a route traverse up the main valley. His map shows the glacier reaching the Hunza river, which passes round the snout. Three miles from the snout the glacier begins to spread, and the track is shown crossing the glacier about half a mile from the snout, which is about 1½ miles broad at this point. Woodthorpe describes the glacier as being 'at least 1¼ miles broad.' He writes that it is 'impracticable for horses, which must ford the main river just above Pasu as well as the Shimshal river 2 miles above it. The horse-road then goes along the river-bed for 3 or 4 miles, fording the stream several times. This is impracticable after 1st May' (*The Gilgit-Chitral Mission, 1885-86*, p. 136).

1889. Younghusband crossed the glacier on his way back from the Pamirs (*The Heart of a Continent*, p. 283).

1891. E. F. Knight, after the Hunza campaign, describes his march on 28th December, as follows: 'A short distance beyond Passu we had to cross a large glacier that descended to the river-bed, picking our way for two miles among boulders of green ice.' The snout appears to have been approximately in the same position as in 1885 and 1913 (*Where Three Empires Meet*, p. 498).

1907. In June, Price-Wood crossed the glacier, but gives no details (*Travel and Sport in Turkestan*, p. 26).

1909. Etherton crossed the glacier, which according to him 'threatened to block the Hunza valley.' This rather vague statement is supported by no evidence. His remark that the glacier is 'creeping forward year by year,' probably refers to the ice and not the snout (*Across the Roof of the World*, p. 50).

1913. In May, I found the glacier snout well in the river-bed, and there was no way past it on foot. Opposite the glacier on the left bank of the Hunza river were the remains of an old moraine, showing that the glacier had at some time reached the far bank (*Records of the Survey of India*, Vol. 6, pp. 17, 51; the end of the Batura glacier can be seen in the distance in Plate 7, opposite p. 17).

1922. Skrine crossed the glacier in June, but does not record the position of the snout. It probably extended to the river-bed (*Chinese Central Asia*, p. 31).

1924. Skrine, in October, records that the Batura glacier was easier to cross than in 1922 (*Chinese Central Asia*, p. 290). This was probably due to summer ablation.

1925. Mrs. Visser writes: 'Right across the river the glacier pushed its way, blocking the whole width of the valley' (*Among the Karakoram Glaciers*, p. 51). Mr. Visser records the same fact, and makes certain observations on the 'dead' ice of the glacier, in the *Geographical Journal*, Vol. 68, p. 466. Khan Sahib Afraz Gul Khan's map shows that the river has managed to keep open a channel between the snout and the left bank. The snout 'spread' appears to have been reduced in width to just under a mile, while the 'waist,' 2½ miles above the snout, is about ¾ mile wide. In *Zeitschrift für Gletscherkunde*, Bd. xvi, 1928, Visser describes the glacier very fully. Here he writes: 'The Batura might be longer were it not that it met on its way a river and a mountain side. The position of the end of the glacier is now such that the Batura stream unites with the water of the Hunza river almost without ever having seen the light of day.'

Conclusion.—The evidence of the moraine on the left bank seems to point to secular retreat; but this is not very recent. If there ever has been a glacier block, the water almost certainly escaped under the ice.[1] The only record of a large catastrophe in the Hunza river, apart from the smaller ones in the Shingshal tributary, is that of 1858, which was almost certainly due to the earthen dam formed by the Ghammesar landslide near Atabad. It is the lake, which formed behind this, and which stretched to and destroyed the old village of Pasu, that has given to the valley here the appearance of having been destroyed by the bursting of a Batura glacier dam.

Apart from the evidence of secular retreat, which cannot be expected to be very marked in a glacier with so small a fall, there

[1] Since the above was written, I have received a letter from Mr. H. Todd, Political Agent at Gilgit, in which he remarks: 'I can find no evidence of a flood of any size in 1873. The people say that the Batura has never caused a flood. It has been known to move across the river, but the water has soon found its way underneath or over the top.' I had already come to the conclusion that the flood caused by a block reported to me in 1913 to have occurred about forty years previously, (*Records of the Survey of India*, Vol. 6, p. 51), had no foundation in fact. (*Himalayan Journal*, Vol. 1, p. 21).

seems to have been a diminution of the width of the glacier 'spread' after its emergence into the Hunza valley from its enclosing walls, though the actual position of the tongue cannot have varied much during the last forty years. During this period the main route to the Pamirs has crossed the glacier at approximately the same spot, three-quarters of a mile from the snout, which has projected up to or into the Hunza river. Visser remarks that the great left side arm of the glacier shows signs of great degeneracy. Everything in fact points to a higher level of the ice a comparatively short time ago. I, therefore, believe that a block by the Batura glacier is not possible, even if it ever was in recent times. Too much water now comes down the main river from the Chapursan, Khunjerab and Ghujerab basins, and end-erosion should always keep a passage clear. It may not be long, relatively speaking, before the glacier may retreat from the river bank and leave a passage up the Hunza valley below the snout, at any rate in winter-time.

(*b*) (ii) SHINGSHAL VALLEY GLACIERS.

The whole Shingshal valley up to the tributary leading to the Shingshal pass was traversed by Lieut. G. K. Cockerill, (now General Sir George Cockerill, Kt., C.B., M.P.), in 1892. He made a rough survey of his route to the pass, which was accurate so far as it went, but the glaciers were not reconnoitred in detail, nor were they studied. In April, 1908, Captain F. H. Bridges, Military Assistant at Gilgit, reconnoitred the whole of the Shingshal valley, and wrote a brief report, which was unfortunately not made public. His observations are most valuable. In April, 1913, Captain J. F. Turner visited the valley, but it was not till the Visser expedition of 1925, that the whole valley and all its glaciers were accurately surveyed.

The following glaciers descend from the Muztagh-Karakoram range, and flowing north, drain into the Shingshal river [1]:—

(9) Ghutalji Yaz.

(10) Lupghar Yaz.

[1] Sir George Cockerill's names for those glaciers are :—(9) Abdigar, (10) Lupghar, (11) Dukul-i-yars, (12) Malunguti, (13) Verigerab. He appears not to have seen the Khurdopin or Virjerab and seems to have been given the name 'Verigerab' for the Yazghil glacier.

Bridges' names for the same glaciers are :—(9) Abdigara, (10) Lupghar, (11) Moombil, (12) Malunguti, (13) Yarsghil, (14) Kurdarpin and Shungdickt, (15) Vergerap.

(11) Momhil Yaz.
(12) Malangutti Yaz.
(13) Yazghil.
(14) Khurdopin, with its tributary, Yukshin-Gardan.
(15) Virjerab.

There have been records of various glacier blocks in the Shingshal valley, caused by one or other of these glaciers advancing and closing the valley. Floods following the bursting of temporary obstructions in the Shingshal are known to have occurred in 1884, 1893, 1905, 1906, and 1927.[1]

9. Ghutalji Yaz.

Sheet, 42 L; *Type*, transverse; *Length*, 9 miles approximately; *Height of Snout*, 11,000 feet approximately; *Fall*, unknown.

10. Lupghar Yaz.

Sheet, 42 L; *Type*, transverse; *Length*, 9 miles approximately; *Height of Snout*, 10,000 feet approximately; *Fall*, 8,000 feet approximately (890 feet per mile, 17·0%).

11. Momhil Yaz.

Sheet, 42 P; *Type*, transverse; *Length*, 18 miles approximately; *Height of Snout*, 9,500 feet approximately; *Fall*, 8,500 feet approximately (472 feet per mile, 9·0%).

The snouts of these three glaciers were shown on Cockerill's map in 1892 to be 3½, 4½ and 3 miles from the Shingshal river respectively.

[1] Early reports placed the obstruction of 1858 on the Hunza river about a mile above Baltit. Later investigation by Drew seemed to place it in the Shingshal valley, though he was correctly informed that it was caused by landslip and not by a glacier dam (*Jummoo and Kashmir Territories*, p. 410). It is quite certain that this obstruction was somewhere up the Hunza river and not on the Shyok, for the gateway of Nomal Fort was discovered among the debris carried down by the flood. From recent investigations by Mr. H. Todd, Political Agent of Gilgit, it seems to me certain that the early reports were correct, and that the obstruction was caused by a landslide at Ghammesar, between Baltit and Atabad (*Himalayan Journal*, Vol. 1, p. 20).

Todd also informs me that the Mir of Hunza in 1929 declared to him that there was no flood in 1927; and Todd himself could find no record of one. The evidence for this flood is contained in Captain Morris's lecture to the Royal Geographical Society (*Geographical Journal*, Vol. 71). The Vissers reported a lake above the Khurdopin glacier in 1925. Todd concludes that the flood must have been very small, if it occurred at all. The lake may have dispersed gradually as happened in 1907.

They are shown only very roughly on Bridges' sketch-map, and Turner does not mention them. On Khan Sahib Afraz Gul Khan's planetable of 1925, they are shown as 4 miles, 4 miles and 2½ miles respectively from the river. The earlier observations may not have been sufficiently accurate for deductions to be drawn, since questions of glacier advance had not then been taken up. Visser (1925) remarks that the Ghutalji Yaz and Lupghar Yaz seem to be the remains of much bigger glaciers. High above the present level of the glaciers, the old beds are plainly visible on the valley slopes.

12. Malangutti Yaz.

Sheet, 42 P; *Type,* transverse; *Length,* 15 miles; *Height of Snout,* 9,700 feet; *Fall,* 4,000 feet in last 8 miles (500 feet per mile, 9·5%).

This glacier was first discovered by Cockerill, but it was not explored till 1925, though Bridges made some interesting observations of its snout. It is fed for the most part by the enormous ice-clothed peak, Dasto-Ghil, 25,868 feet high. Visser reports that streams of névé tumble down from the higher terraces in gigantic falls to unite in the Malangutti glacier, which first of all has an ice-fall, but afterwards flows with a more or less even gradient of about 4·7 per cent. According to the survey made during the expedition, however, this gradient is steeper, 9·5 per cent. The surface had not many crevasses, but presented innumerable gigantic seracs which tumbled together the whole day long. In its lower course there were five lateral moraines, and on both banks there were ablation valleys more or less well-developed.

Visser also writes :—'The Shingshal valley relative to the Malangutti is steep. The Shingshal river pushes its way only with difficulty between the northern slope of the valley and the ice of the Malangutti glacier which spreads over the valley.' There seems to be some error here, for, though for about a mile above the glacier the Shingshal river flows through a narrow gorge, the survey definitely shows the fall of the Shingshal valley as only 84 feet per mile, or 1·6 per cent. approximately.[1]

The upper Shingshal valley is, in fact, mainly a longitudinal trough, roughly parallel to the alignment of the Muztagh-Kara-

[1] The District Engineer of the Gilgit Agency in the time of Bridges' visit commenting on the latter's report, says that the fall in the Shingshal valley is even less than shown on the Khan Sahib's map, *viz.,* 75 feet per mile, or 1·4 per cent.

koram, and the glaciers descending from the latter, which we are considering, are mainly transverse.

The following is a summary of the observations :—

1892. The snout of the glacier is shown on Cockerill's ¼-inch reconnaissance-map as just reaching the Shingshal river, which then found its way round the base.

1908. Bridges found the snout about 50 yards from the opposite conglomerate hill, beyond the bed of the Shingshal river, which flowed under the glacier.[1]

1913. In April, Captain J. F. Turner found the snout projecting to the edge of the river. He was able to ford the Shingshal river below the snout and pass the glacier by the right bank (*private letter*).

1925. The Vissers explored the glacier for three marches and surveyed it thoroughly. As mentioned above, the glacier reached the Shingshal river, which pushed its way with difficulty between the northern bank and the ice of the glacier. Visser considered that the glacier was probably advancing, and that there was danger of damming (*Zeitschrift für Gletscherkunde*, Bd. xvi, 1928, p. 210; see also *Geographical Journal*, Vol. 68, p. 464, and *Among the Karakoram Glaciers*, pp. 157-175).

1927. Captain Morris records that this glacier runs right down to the Shingshal river, 'but exhibits signs of retreat' (*Geographical Journal*, Vol. 71, p. 518).

Conclusion.—This is a typical instance of a glacier projecting into a river which carries sufficient water now-a-days to keep a channel clear, either by erosion or by tunnelling. Except for very minor oscillations in the river-bed, it seems that its snout has remained practically stationary for over 35 years. Yet it has a sufficient fall in its bed and a sufficiently large névé basin to give it a noticeable periodic variation. End-erosion must be the cause of the apparent stability of the snout. According to Bridges, there is some evidence on the valley walls that the glacier has at times blocked the valley. This cannot have been in recent times, and

[1] Bridges reports from local information that in 1907 the glacier closed on this hill opposite, causing a lake to form upstream of it, 150 feet deep. This lake is reported to have burst in September. The District Engineer records that in April, 1907, the glacier was 100 yards from the opposite hill and that there was no lake in August. He dismisses this 1907 flood as fictitious, and he is almost certainly correct. There was actually no serious flood in the Shingshal valley in 1907, and when the lake behind the Khurdopin glacier reached the top of the glacier its waters dispersed gently in eleven days. The rise at Bunji was only 7 feet.

such an event is no longer likely. In any case such evidence points to secular retreat. The glacier may also be retreating now, as suggested by Morris in 1927, but it would be unwise to accept this as a definite conclusion until it is shown to have retreated from the river bank. Morris was there in 1927, when there was a block further up the river; the water in the Shingshal river may therefore have been less than normal. It is just possible that the low river may have given Morris an exaggerated impression of retreat.

13. Yazghil Glacier.

Sheet, 42 P; *Type*, transverse; *Length*, 18 miles; *Height of Snout*, 10,400 feet; *Fall*, 6,500 feet (360 feet per mile, 6·8%).

Except for some careful observations at the snout of this glacier made by Captain F. H. Bridges in April, 1908, almost all our knowledge comes from Visser, but it is not easy to agree with some of his conclusions. He says, for instance:—'This is the most easterly and the largest of the five glaciers which flow in purely *longitudinal* valleys, within the drainage area of the Shingshal.' I personally believe that this glacier, as well as the remaining four to its west, is typically transverse.

The Yazghil valley is heavily deepened compared with its upper three left side-branches, from which the glaciers hang with lovely falls of ice. These glaciers have basins narrowly shut in by steep walls of rock and are fed entirely by avalanches. The total fall of 6·8 per cent. is broken twice by ice-falls, and but for these the gradient would be an even 5·2 per cent.

Visser remarks on the spotless whiteness of this glacier compared with others in the Shingshal region. Ablation valleys extend on either side of the main valley along the lower course. The following observations give a summary of what is known of the position of its snout.

1892. On Cockerill's sketch-map this glacier, which is called the 'Verigerab,' is shown as just reaching the Shingshal river.

1908. Bridges reports that the snout is split into two before reaching the river-bed, by a hill situated in the mouth of the side valley. The two snouts thus formed were three-quarters of a mile apart. The upper snout was 48 yards and the lower only 10 yards from the cliff on the right bank of the Shingshal. According to native information, the lower snout had during the previous year

extended to the opposite cliff and the water had flowed all the time underneath the ice. The flood caused by the Khurdopin in 1907, in spite of the fact that it took eleven days to drain away, cut through the Yazghil dam and demolished it (*unpublished report*).

1913. Captain J. F. Turner does not appear to have observed the Yazghil glacier when passing up the main valley. It is possible that at this time the glacier was not then projecting into the Shingshal river-bed (*private letter*).

1925. On the Khan Sahib's map, surveyed during the Visser expedition, the glacier is shown as completely blocking the main valley, but no lake is shown upstream of it, and Mrs. Visser writes that it entirely filled the broad Shingshal valley, so that the river had to force its way beneath the ice (*Among the Karakoram Glaciers*, p. 109). According to the same map the glacier seems to have spread slightly upstream and about half a mile down-stream in the valley of the Shingshal. (For a description of the exploration of this glacier, see *op. cit*, p. 138; and photographs in *Geographical Journal*, Vol. 68, p. 466.)

Visser himself writes that the Yazghil appeared to be in a state of advance, 'because the snout of the glacier had pushed itself across the Shingshal valley, and had forced the river over to the right bank.' This last remark is slightly at variance with the other observations noted above, but there seems to be little doubt that the conclusion is correct. The intense whiteness noted by Visser is strongly typical of an advancing glacier in these regions, as is the fact that the glacier seemed to be spreading its snout in the main valley and seeking to find room for its extra volumes of ice in its own valley itself. The old dead lateral moraines at some places completely and at others partially, had been swept away by the advancing ice, so that they formed at the side of the glacier a vertical wall.

Conclusion.—Though there is very little actual change in the position of the snout between 1892, 1908, and 1925, it appears to me that this glacier is now definitely trying to advance. The advance of the snout is, however, cloaked by the activity of the main river and the extra volume of ice has to find relief by spreading rather than advance. Bridges recorded that in April, 1908, the river upstream of the glacier was dry, mainly due to the block caused by the Khurdopin, but also undoubtedly owing to the early month of the year. Visser recorded that he was unable to find any trace

of a previous lake above the glacier. It seems to me quite clear that the Shingshal waters are able to maintain their channel either underneath or round the ice of the Yazghil, especially as neither Montagnier nor Morris recorded any lake or block in 1927, and the valley does not appear to have been blocked in recent years.

The movements recorded above are almost certainly periodic, and no secular variation in the snout has yet been observed.

14. Khurdopin Glacier.

Sheet, 42 P; *Type*, transverse; *Length*, 26 miles; *Height of Snout*, 10,600 feet; *Fall*, 9,000 feet (346 feet per mile, 6·6%).

The first European to see the Khurdopin glacier was Bridges, in 1908, but nothing was known about its great extent till the important discoveries of the Vissers in 1925, when it was accurately surveyed throughout its entire length.[1]

Visser considers that it is 'more transverse than longitudinal.' He is probably correct in surmising that some of its ice-supply is derived from the great snow-lake source of the Biafo glacier, that enormous reservoir above the permanent snow-line which would be capable of maintaining the Hispar, the Biafo, the Khurdopin and the Virjerab glaciers.

The Khurdopin glacier is compound, with two large head-basins and numerous side-glaciers which add their ice to the main trunk. The bed of the Khurdopin is deep compared with that of its tributaries.

The longitudinal profile of the Khurdopin glacier has a very large break close to the southern side-branch, and although the glacier below this ice-fall traverses an evenly sloping valley-bed, with a gradient of about 3·8 per cent, the surface of the ice throughout is broken up into typical trans-Muztagh ice-pinnacles. Only in the last 3 or 4 miles do they change to more rounded forms, towers and humps covered with debris. It is also only in these last 3 to 4 miles that the debris is present; for the rest, moraine is represented by two dark median lines.

[1] Bridges records: 'At various times men have been sent by the Mir of Hunza to try and penetrate to their head [of the Khurdopin and Virjerab glaciers] but they have always returned unsuccessful. One levy, by name Murad Beq, who accompanied me, had been four marches into both of them during the time of Rajah Ghazan Khan. He said he could see no signs of the heads of the glaciers and returned as he had finished his rations.'

Among the pinnacles, crevasses are rare, and surface water between the towers and pinnacles forms for long distances broad and deep impassable rivers.

An ablation valley along the northern bank is present, filled in its lower course with stream-deposits, which give a good soil for countless beautiful Alpine flowers, and lakes. Many of these small glacial lakes would be dangerous to anyone camping below them in the valley. On the southern bank the ablation valley only extends for about two miles. Here the formation is complicated by the junction of the Yukshin-Gardan tributary.

Visser notes that the Khurdopin glacier has a very small névé area of only 66 square kilometres. The region of melting is 184 sq. km. The relationship is therefore approximately 1 : 3. Observations of the Khurdopin glacier are summarized below.

1908. Captain Bridges writes :—'The Kurdarpin and Shungdickt[1] glaciers have swept down through their own *nullah*-beds, and meeting in the main *nullah*[2] have gradually moved on down, till they now extend in one huge glacier filling the entire main *nullah*-bed for a distance of about two miles below the mouth of the Vergerap *nullah* and within about 1½ miles of the upper snout of the Yarsghil...The united glaciers of Kurdarpin and Shungdickt, sweeping past the mouth of the Vergerap and impinging along the whole cliff-face below Vergerap for about 1½ miles, have enclosed a large open space at the mouth of the Vergrap *nullah*.'[3]

[1] *i.e.*, the Yukshin-Gardan glacier.

[2] *i.e.*, the main Shingshal valley.

[3] I quote here in full from Captain Bridges' report, so far unpublished, for it gives a good account of how it is possible for a glacier to act as a weir and to allow the waters of the lake to disperse gradually :—

'I went to the edge of the dam, overlooking the above space. It is difficult to estimate its size accurately, looking down on it like this ; but I should say roughly that it extends for about 3 or 4 miles in length and varies in width from 100 to 300 yards at its base, and would of course increase in width as the water rose. At present there is water in it for about a mile in length ; but it is impossible to make any accurate estimate of its depth. The local men estimate its present depth at the lower end at about 20 or 30 feet. I should not think it was more. Some of the Hunza men got down by ropes to the lake to try and measure its depth, but had to abandon the attempt, owing to falling rocks and debris. I could see the water-line of last year's flood on the rocks and should say that the water did not reach a greater height than 200 feet, though this is a rough guess, as without proper surveying instruments, it is impossible to make an accurate estimate. The surveyor however sent up by the District Engineer will be able to do this. The water in the lake, I am told by the local men, stretched as far back as the snout of the Vergerap glacier last year, and I could see the water-line on the rocks of the Vergerap *nullah*. The water, according to the men told off to watch it, rose last year till it overflowed the top of the glacier, where it impinges on the right bank, and then cut its way clean through the glacier. This is undoubtedly true. There is an enormous channel,

1913. Captain Turner reports that the snout of the Khurdopin glacier was still right across the main valley. He crossed the snout, the width of ice being estimated by him to be about three miles. At the extreme end it was approximately 200 feet deep, and there were many crevasses closed by ice-bridges, under which the main river found its way. There was no lake upstream of the glacier in April of this year, but Turner considered that it would be possible at any time for the crevasses to be closed and a complete block formed (*private letter*).

about 150 feet deep and 80 to 100 feet wide, cut clean through the ice like a huge canal, at the lower end of the lake. This has water in it now. I went to the edge of it and looked down into it, and have told the surveyor to go to the same place and measure the depth of the water with a plumb-line. This canal is closed by an ice-dam now lower down; this dam is, I should say roughly, about half a mile, or perhaps a little less, from the outlet of the lake. It is impossible to find out what is the nature of the glacier between this dam and the snout along the right bank. Last year's flood has broken up the glacier a good deal, and left enormous crevasses all along its right bank, and consequently it is impossible to reach this part. One of the Hunza men managed with difficulty to reach a spot from which he could see the dam blocking the canal, but could get no further. From questioning him I should say it was about 100 feet above the present water-level. The water breaking through last year has caused the whole of the glacier on the right bank to sink a good deal. The centre remained much higher; but both on the right and left banks of the *nullah*, the glacier is at a much lower level. There was a perpendicular wall of ice with no apparent fissures about 100 or 150 feet from the *nullah*-bed across last year's outlet, which is now closed. The distance between the snout near the right bank and the ice dam in the canal is, I should think, roughly about $\frac{3}{4}$ of a mile. My camp was in the *nullah* within 200 yards of the snout of the glacier. My aneroid showed a rise of 800 feet from my camp to the highest point in the centre of the glacier between my camp and the lake. The distance from my camp to the lake was, I should say, about 2 miles.' (The District Engineer comments that the *lowest* point of the dam is 180 feet above the present water-level in the lake.)

'Unless the glacier moves forward again and piling up against the hill, closes last year's channel, I should say that the lake will not rise as high this year as it did last, as all the local men agree that last year's bund was a good deal higher. There is on the other hand the danger of the bund this year suddenly bursting when the lake is full, instead of the water gradually cutting a way as it did last year. The water last year from the lake took eleven days to empty. Hence the small rise of water. If the canal dam suddenly broke or the water forced a way under the glacier, the lake would empty in a few hours and a very large volume of water would come down, if the lake was full at the time.' (The District Engineer comments that "from the end of the canal to the snout of the glacier on the downstream side is one mile. The existing dam is therefore very strong.") 'I think the water this year is bound to follow the same course as last year, as the stretch of canal left by last year's flood will bring the pressure to bear chiefly on this portion of the glacier. I placed three pillars of stones in a line, close to the present canal, so that the surveyor, while working there, can watch them, and see if the glacier is closing in on the canal. The local men tell me that the channel is narrower now than it was after the flood last year .....'

The District Engineer has made a few comments in the margin of the report. He remarks that the area available for the lake above the Khurdopin glacier is 2 miles long with a mean width of 1 mile; that the lower end of the lake at the time of the surveyor's visit was calculated at 150 feet, and that the water-level rose, according to the mark pointed out by the local people, 140 feet above the existing level. The mean width of the channel cut by the 1907 flood was 50 feet and its depth 100 feet. The glacier was not closing in on the channel.

1925. The Vissers found that the glacier had definitely turned down the main valley, and completely blocked the valley. A considerable lake had formed upstream of the block, and only a small portion of its waters found an outlet beneath the glacier. Visser noted the terraces along the banks of the lake above the existing level of the water, and calculated that about 360 to 480 millions cubic metres was about the capacity of the lake when full (*Zeitschrift für Gletscherkunde*, Bd. xvi, 1928, pp. 203-206 ; see also *Among the Karakoram Glaciers*, pp. 128, 136 ; and *Geographical Journal*, Vol. 68, pp. 464, 465).

Conclusion.—There is no doubt that this is the glacier that has been periodically responsible for the floods of the Shingshal valley. These floods are known to have occurred in 1884, 1893, 1905, 1906, with minor ones in 1907 and possibly 1927. There is constant danger of a complete block. Probably at the season of the year from July to September there is always a lake, for the drainage into the lake then exceeds the percolation out of it. In April, 1908, there was a lake, but in April, 1913, there was none. These two years are comparable, for the observations were taken at the same season. The height of the ice at the end was 330 feet in 1908, and estimated at 200 feet in 1913. Its width in 1908 was about 1½ miles ; in 1913 it was estimated to be 3 miles wide. The years 1905 to 1907 are known to have been during a period of advance. The flattening of the snout and its spreading are signs of retreat between 1908 and 1913. The observations of 1925 are not directly comparable with the earlier ones, but Visser also records signs of shrinkage in volume, and the side tributaries, particularly that on the right bank, show marked signs of great degeneracy.

As with all glaciers projecting into a river-bed it is not easy to draw definite conclusions, nor to state whether there is any periodicity in the movements. It is, however, a fair assumption that the movements causing the blocks are either seasonal or periodic, and not secular, while if there is any secular variation the decrease in volume and degeneracy seem to point to secular retreat.

15. Virjerab Glacier.

Sheet, 42 P ; *Type*, longitudinal ; *Length*, 24 miles ; *Height of Snout*, 11,320 feet ; *Fall*, 4,800 feet (200 feet per mile, 3·8%).

The Virjerab glacier fills the head of the longitudinal trough of the Shingshal valley. Its snout was visited by Captain Bridges in

1908, and by Captain Turner in 1913, but no part of it was explored, nor was its great extent known until the visit of the Vissers in 1925. Visser himself says that no other glacier gave them such cause for astonishment as this, for no part of the true body of the glacier ascends above the permanent snow-line. It, therefore, has no névé area of its own, and is fed almost exclusively by avalanches. At its extreme southern end it is joined to the permanent snow-line of the main range by steep broad ice-couloirs, and the range here probably is the boundary ridge of the great snow-lake described by Conway, which certainly feeds the Hispar and the Biafo glaciers and very possibly the Khurdopin and to some extent the Virjerab as well. The tributary glaciers also are insignificant, and Visser estimates that the whole névé area of the main glacier and its tributaries combined is only one-fifth of the area under melting. For ten miles from its snout its surface is entirely covered with a thick deposit of rubbish. Ablation valleys were scarcely visible, being presumably filled by disintegrated rock debris, which daily tumbles down in large quantities from the mountain-sides and immediately mixes with the debris on the glacier.

1908. According to the surveyor sent up by the Gilgit Engineer, the Virjerab glacier snout was 2 miles from the east wall of the Khurdopin. At the time of Bridges' visit the extent of the lake was one mile in length.

1913. Turner found the snout of this glacier from half to three-quarters of a mile only from the east side of the Khurdopin glacier. As mentioned above, when describing his observations of the Khurdopin, no lake had then formed between the two (*private letter*).

1925. The Vissers found that the snout was approximately 1½ miles from the east wall of the Khurdopin, and drained into the lake upstream of the latter. This lake has been briefly described above, and full details are given in *Among the Karakoram Glaciers*, pp. 130 *et seq.* Without knowing Turner's observations Visser concluded that the Virjerab glacier was retreating. On the banks there were clear signs of a higher position of the ice not very long ago, and Visser thinks that at that time the glacier probably joined the Khurdopin.

Conclusion.—It is difficult to see how this glacier with its comparatively small area of névé, can maintain so great a length, and everything seems to point to definite secular retreat. The whole of the last ten miles of the glacier appears to be in a dying condition

Nor do the ranges bounding the trunk of the glacier seem high enough to maintain a sufficient supply of ice to feed the glacier. The absence of terminal moraine-banks is curious, but they are probably levelled by the action of the lake. The waters of this glacier will always remain a danger to the Shingshal valley as long as the Khurdopin glacier projects so far into the valley.

The mountain-walls are here in such a constant state of denudation and change, and so much rock is thrown upon the glacier, that, in spite of the paucity of observations, it seems to me that this glacier is very definitely shrinking both in length and in volume.

(*b*) (iii) MISCELLANEOUS GLACIERS OF THE KHUNJERAB-GHUJERAB REGION.

The four glaciers of which brief details are given below, have only been examined by the Vissers, and the notes that follow are abstracted from their writings in *Zeitschrift für Gletscherkunde*, Bd. xvi, pp. 210-213. The four glaciers are :—

(16) Parpik (Bara Khun group),
(17) Kuksel (Ghujerab group),
(18) North Maidur (Shingshal group),
(19) South Maidur (Shingshal group).

Visser says that these have the following features in common :—

(*a*) Very little moraine rubbish, (*b*) a steady gradient, (*c*) few medial crevasses, and therefore (*d*) few seracs. In consequence, there are surface river systems, but except on the North Maidur, no lakes exist either on or beside the glaciers. Ablation valleys are present, but are not well-marked.

16. Parpik Glacier.

Sheet, 42 P ; *Type*, Transverse ; *Length*, 8 miles ; *Height of Snout*, 14,300 feet ; *Fall*, 500 feet per mile (9·5 %).

1925. The glacier has a small break in its otherwise even fall, and consequently an ice-fall in its lower course. The broad swollen snout ends in an almost perpendicular wall, pushing forward rubbish and causing havoc among the grass and flowers at its edge. No marked terminal moraines indicated former advances, but the right valley wall above the snout showed signs of a wider and higher situation for the glacier not very long ago. Further down the valley the slopes were so covered with boulders that no conclusions could be formed.

Conclusion.- The glacier is undoubtedly advancing, and this advance is almost certainly periodic. The snout in 1925 was typical of an advancing one. Over long periods of time, however, there are indications of diminishing volume and secular retreat.

17. Kuksel Glacier.

Sheet, 42 P; *Type,* Transverse; *Length,* 4 miles; *Height of Snout,* 15,000 feet; *Fall,* 500 feet per mile (9·5%).

1925. Visser does not give any details of the snout, but concludes that it is stationary.

18. North Maidur Glacier.

Sheet, 42 P; *Type,* Transverse; *Length,* 6 miles; *Height of Snout,* 14,930 feet; *Fall,* 330 feet per mile (6·2%).

1925. Visser observed that the glacier consisted of two branches which unite about 2 miles from the snout. Both branches have no snowfields and lie in enclosed basins. He concluded that the glacier was certainly not retreating, but was probably stationary.

19. South Maidur Glacier.

Sheet, 42 P; *Type,* Transverse; *Length,* 1½ miles; *Height of Snout,* 14,000 feet; *Fall,* 2,000 feet per mile (38%).

1925. The Vissers observed a dead end to this glacier, the snout being detached. They suggest that this end may have been detached by an earthquake, for it was covered by rubbish and was therefore existing under unfavourable circumstances. In the living part of the glacier there was a strange phenomenon: the living end divides into two short tongues, one of which shows every sign of retreat, while the other indicates rapid advance.

PART II. BALTISTAN-LADAKH.

(a) GLACIERS SOUTH OF THE MUZTAGH-KARAKORAM RANGE.

THE BRALDOH VALLEY.

20. Biafo Glacier.

Sheet, 43 M; *Type,* Longitudinal (mainly); *Length,* 37 miles (including Snow Lake); *Height of Snout,* 10,360 feet; *Fall,* 16,290 to 10,360 from edge of Snow Lake to snout, 28 miles (212 feet per mile, 4·0%).

The Biafo is the fifth longest glacier outside sub-Polar regions. It descends from an enormous snow basin which has an area of some 25 square miles. This enormous reservoir, which has been described as a region 'drowned in ice,' though seen by Godwin Austen, Sir Martin Conway and the Workmans, has not yet been fully surveyed, but it is believed not only to supply ice to the Biafo glacier, but to force ice over the Hispar pass to the Hispar glacier and over the main Muztagh range to the heads of the Shingshal glaciers, the Virjerab and Khurdopin. The Biafo glacier itself is fed by some ten branches on the southern side, but with the exception of the Latok glacier, there are none of any importance on its northern side. The ratio of supply area to waste area is as large as 3 : 4. Near the entrance to the Snow Lake the glacier has a width of about 2½ miles, but it narrows to a mile at six miles from the snout. It is possible that this narrowing is partly responsible for the marked variations of the snout, which are unusual for a glacier of so gentle an average fall. The longitudinal profile is broken at two places, at six and at eleven miles from the snout.

The following are the most important observations that have been made regarding the snout variations of the Biafo glacier :—

1861. Godwin Austen surveyed the glacier and found the snout filling the whole Braldoh valley from one side to the other, and resting on the rocks of Mango Gusor on the left flank of the valley, in such a way that the Braldoh river, containing mainly the waters of the Punmah and Baltoro glaciers, flowed in a tunnel underneath the ice. His map shows a complete block and the track is shown crossing the glacier 1½ miles from the snout.

1892. On 31st July, Sir Martin Conway found the snout a quarter of a mile away from the Mango Gusor wall of the valley, and noted that during August of that year it lost another quarter of a mile As it withdrew, it left before it a wide moraine covered with earth and vegetation.

1899. The Workmans found the glacier so shrunk that it barely reached the outlet into the Braldoh valley at all. It would then have been about a mile from the Mango Gusor wall on the left bank of the river.

1902. According to Guillarmod, the glacier had again advanced as far as the right bank of the Braldoh river driving before it a low frontal moraine. Dr. Pfannl, of the same expedition, does not mention this frontal moraine, and describes the Biafo as a mass

600 to 700 feet thick, protruding across the valley, squeezing the Braldoh into a narrow bed, and ending with a steep snout 400 feet above the river (*Mitt. d. Geog. Ges. Wien*, 47, 1904, p. 255).

1905. Colonel Penny records from memory in 1928, that in 1905 the low snout of the Biafo glacier was a mass of fissured broken ice 'extending to the right side of the Braldoh river and there seemed no practicable passage there.' His guides confirmed the Workman's statement of 1899 (private letter). The low fissured snout indicates that the glacier was now retreating and diminishing in volume.

1908. The Workmans on their return to the region noted that the Biafo was practically in the same position as they had found it in 1899. If this observation is correct, the glacier must have grown and shrunk again between their two expeditions.

1909. De Filippi, during the Abruzzi expedition, found the glacier projecting right into the Braldoh valley, and thought at first that it blocked the river. He writes: 'It was only when on our return journey we ascended the left side of the Braldoh valley on the Skoro La road that we clearly saw the river flowing under the open sky through a narrow gap between the valley wall and the steep front of the glacier. The latter showed no trace of frontal moraine. It is, however, possible that at some point of the left half of the glacier the ice may bridge over the river and actually reach the rock' (*Karakoram and Western Himalaya*, p. 165).

1922. Featherstone found the snout right up to the Braldoh river, and according to natives it had been so for two years. They also said that the glacier was forcing the river to cut into the opposite bank, causing great land-slides (*Geographical Journal*, Vol. 67, 1926).

1923. Egeberg reported that the Biafo stream could be crossed below the snout of the glacier owing to the retreat of the latter (*private communication*).

Conclusion.—It is unusual for a longitudinal glacier with so gentle a fall to show such marked periodic or seasonal movements, and it would be well worth studying this glacier more carefully and in more detail, in spite of the fact that end erosion must to some extent vitiate the observations when the glacier actually projects into the river-bed. It is inconceivable that this glacier could block the combined waters of the Punmah and Baltoro glaciers, which should always be able to maintain a cannel.

The period 1861 to 1892 is too long, in view of later observations, to assume that the snout remained more or less stationary during that period; but from the latter year to 1899, there seems to have been a steady retreat. A sudden advance then set in, but by 1905 degeneration and retreat had again commenced, reaching a maximum about 1908. Another rapid advance had set in by the following year, and the glacier was in approximately the same position in 1922, though again beginning to retreat.

These movements must be considered seasonal or periodic. The fact that the snout was in practically the same position in 1861 and in 1922 seems to indicate that there has been no secular movement of any importance during these sixty years.

21. Punmah Glacier.

Sheet, 43 M; *Type,* Transverse, compound with longitudinal tributaries; *Length,* 17 miles to head of Nobundi Sobundi branch; *Height of Snout,* 11,900 (?); *Fall,* unknown.

The Punmah glacier was first visited by Rudolf Schlagintweit in 1856, and first sketched by Godwin Austen in 1861, but neither of the two great western longitudinal tributaries, the Choktoi Gans or the Nobundi, Sobundi, were actually visited by him. He did, however, explore the eastern longitudinal branch of the Chiring glacier, but failed through bad weather to reach the western Muztagh pass at its head, leading to the Sarpo Laggo glacier tributary of the Shaksgam. He was followed in 1887, by Sir Francis Younghusband, who, however, did not reach the pass; by Featherstone in 1922, who reached the mouth of the Chiring glacier; and by a party from the Duke of Spoleto's expedition in 1929. The observations of the last are not yet available.

Godwin Austen recorded that the glacier had in 1861 advanced so as to cover the path for some distance, but no observations of the position of the snout appear to have been made by any of the later travellers, though there are reports that the pass has been blocked by an increase of ice near the summit of the main range. Such a statement must be accepted with reserve.

22. Baltoro Glacier.

Sheet, 52 A; *Type,* Longitudinal; *Length,* 36 miles; *Height of Snout,* 11,580 feet; *Fall,* 450 feet per mile (8·5%).

The head basin of the Baltoro glacier is complicated. The extreme point of the main trunk lies south-east of Gasherbrum, but it is joined almost within 10 miles by masses of ice from the northern flanks of the 'Bride Peak', and some 20 miles from the snout the great northern tributary, the Godwin Austen glacier, draining three sides of K^2, joins it at Concordia. The glacier receives numerous smaller tributaries, though still of much importance, on both flanks, throughout its length. There are no marked ablation valleys between the main body and the valley walls, but at one or two spots the glacier leaves an open space.

Godwin Austen in 1861, was the first to realize the great length of this glacier and to put it on the map.[1] In 1891, Sir Martin Conway made a large-scale survey of the main glacier as far as the Golden Throne (*The Karakoram Himalayas*, Sheet II, published by the Royal Geographical Society, scale 1 inch — 2 miles). For his description, see *Climbing in the Himalayas*. The whole of the upper 27 miles of the glacier and its branch tributaries were re-surveyed on the Duke of the Abruzzi's expedition of 1909, and described by Sir Filippo De Filippi in his book, *Karakoram and Western Himalaya*.

A further survey has been made by stereography by the Duke of Spoleto's Italian expedition of 1929. The details of this are not yet available.

1861. Godwin Austen visited and surveyed the glacier.

1892. From Conway's photographs, the snout appears to be in the same position as in 1861, though Godwin Austen himself considered that the glacier had advanced slightly down the valley.

1902. Dr. Pfannl shows an illustration in *Zeit. d. deut. u. oest. Alpenver*, 35, 1904, p. 96, which indicates that the Baltoro snout was in the same position in 1902 as in 1892 and 1909.

1903. Montagnier reported to De Filippi in 1910, that in 1903 he found the glacier more to the right side of the valley and pressing against the right moraine. If this observation is reliable, it would appear that the glacier was then about 300 yards in retreat from its position in 1892, 1902 and 1909.

1909. De Filippi writes: 'The snout of this glacier still corresponds absolutely with the description of it given by Conway in 1892. It may possibly be stationary, but certainly shows no sign

[1] The Baltoro glacier is believed to be equal in length to the Batura and therefore the sixth longest glacier outside sub-Polar regions.

of shrinking' (*Geographical Journal*, Vol. 67, p. 20; photographs in *Karakoram and Western Himalaya*, p. 174).

Conclusion.—There appears to be practically no periodic movement; the glacier would therefore be suitable for secular observations, and marks should be carefully made for this purpose.

THE NUBRA VALLEY.

As yet we are not in a position to draw conclusions regarding advance or retreat of the glaciers of the Nubra valley. Practically every observer has drawn attention to the fact that the great longitudinal valley glacier, the Siachen, at one time occupied the whole Nubra valley down to its junction with the Shyok. Drew mentions this fact and gives the total depth of the glacier as having been about 4,000 feet. Subsequent travellers doubt this great depth, but all agree that the solid rock for hundreds of feet above the river has been polished, rounded, and scratched by pressure down to the Nubra-Shyok junction (Longstaff, in *Geographical Journal*, Vol. 35, p. 640; Visser in *Zeitschrift für Gletscherkunde*, Vol. xvi, p. 229). If further evidence were needed, it is to be found in the condition of the tributaries. The glaciers were first left hanging above the Nubra valley, when the main glacier retired; since then they have retreated, and their waters, laden with moraine, have carved narrow marginal gorges (*Records of the Survey of India*, Vol. 22, p. 15).

The glaciers about whose snouts a little is known are only two: the Siachen and the Mamostong.[1] Visser draws tentative conclusions from four or five small glaciers of the Thulanbuti stream, descending from the Saser pass, and the two glaciers of the Popache Lungpa. These last he places in his Saser group. He writes: 'A very considerable part of the group is entirely covered with névé, from which streams of ice pour down to the valleys. The plateau out of which the range rises, is itself at a considerable altitude. One would expect a far greater development of glaciers than there is, when one considers the uninterrupted covering of ice and snow, and the great altitude of the most important peaks of the central zone. There are indeed numerous glaciers, but of all those we examined, only one attained a length of 10 kilometres, and not one extended below 4,800 metres. The névé-line, or the temporary snow-line, was about 5,500-5,600 metres, considerably higher than

[1] The Mamostong was shown on old maps as Murgisthang

in the Hunza region. Till about half-way down there is not much debris on any of the glaciers; but then it increases rapidly, so that usually the snout is buried under enormous masses of rock, which therefore points to increasing ablation. The gradient of the tongue is generally regular, and for these short glaciers (excluding hanging glaciers) is comparatively small, 11-14%.....As everywhere else in the Karakoram, here too we found ablation valleys,—so characteristic of these warm regions.....We received the impression that the glaciers in the part of the Saser group visited by us were, on the whole, advancing. Nearly all of them ended in a very steep snout, which was pushing moraine material in front of it. The Changmolung glacier was an exception; it ended in a flat tongue. As only two Europeans, Longstaff and Neve, had previously been into this region, and only into one valley, there was no information about these glaciers that we could use as a basis for comparison. Whether the glaciers have lately been growing or otherwise we must therefore leave an open question; but there is evidence that not long ago, they were of greater extent than they are now' (*Zeitschrift für Gletscherkunde*, xvi, pp. 217-222). It seems to me that the advances indicated by Visser are periodic. Neither Longstaff nor Neve venture any opinion as to whether the glaciers were advancing in 1907 and 1909, nor do they give any clear indication of the positions of the snouts.

Two glaciers only will, therefore, be described in more detail in the Nubra region, the Siachen and the Mamostong, and even from these no conclusions can be drawn.

23. Siachen Glacier.

Sheets, 52 A and E; *Type*, Longitudinal; *Length*, 45 miles; *Height of Snout*, 12,150 feet approximately.[1] *Fall*, 194 feet per mile (3·7%).

The Siachen glacier is the longest glacier[2] outside Polar or sub-Polar regions, but its great length was unknown until the explorations of Dr. Longstaff in 1909. As long ago as 1848 Henry Strachey ascended the glacier for two miles. He remarked on the

[1] Longstaff gives the height of the snout as 11,600 feet while the gazetteer gives 11,700 feet, derived from Henry Strachey's figure. The height 12,150 is from the survey of 1862. Probably none of these can be relied upon to within 300 feet.

[2] Since the above was written I have been informed by Mr. Rickmers that the Fedchenko glacier of the North-Western Pamirs has been found to be 48 miles long. The Siachen glacier is therefore the second longest glacier outside sub-Polar regions.

even level maintained by the glacier, the abrupt contact of the ice with its confining walls, the unusually large amount of bare ice exposed by the moraines and the excessive crevassation of the ice (*Physical Geography of Western Tibet*, p. 53). The snout was also reached in the same year by Dr. Thomas Thomson, and reconnoitred by the Survey of India in 1862. Unfortunately the position on the map cannot be relied on, and little information of importance can be gleaned till Longstaff visited it in 1909. His discoveries of that year and the detailed surveys of the Workmans in 1912, show that no big glacier tributaries actually join the main glacier in the first 25 miles of its length. Some four miles from the snout, however, the Vissers in 1929 discovered the snout of another large glacier distant some six miles from the Siachen. Their report on these will be awaited with interest.

A little over 25 miles from the end of Siachen glacier, the Lolofond and the Teram Shehr tributaries (the latter 15 miles long) join the main trunk from the west and east respectively. Beyond this again the head is split in two by a range descending from Gasherbrum in a south-east direction.

Longstaff ventures a suggestion that the glacier has advanced between 1862 [1] and 1909, from an examination of the difference of height at the snout between the two dates, but these heights cannot be considered of sufficient accuracy to warrant such a deduction, and the approximate value, 12,150 feet found by the Survey of India in 1862 definitely precludes this untrustworthy evidence.

The snout of this glacier is unfortunately difficult to approach between the months of June and October, and so it is inaccessible to most travellers to the Nubra. But it would be of value if its position could be marked, so that further observations could be made occasionally.

24. Mamostong Glacier.

Sheet, 52 E; *Type*, Longitudinal; *Length*, 10 miles; *Height of Snout*, 14,550 approximately; *Fall*, 500 feet per mile (9·5%).

Dr. Arthur Neve in 1907 was the first to explore this glacier. He records that the lower 6 miles were a mass of chaotic ice hummocks and moraines, and that it is joined by extensive transverse ice streams pouring in on each side, those on the east coming from

[1] Presumably he means 1848, the year of Henry Strachey's visit.

precipitous peaks, those on the west flowing from wide snow-fields. Neve writes: 'There were no signs of any recent retreat of the snout; the lateral moraines are only well-marked for about a hundred yards beyond the present ice-cave, from which part of the river originates. There is a second source several hundred yards to the left (north-west) along the ice-wall, which varies from 50 to 100 feet high. The portion of the snout which crosses over the valley and rests against the southern slopes was nowhere more than 200 feet high and 100 yards broad, and the large stream from the Saser pass tunnels under it. Above the tunnel is a small sandy plain about a quarter of a mile long, and half that breadth, which looks like a recent lake-bed, and evidently within the last ten years the Murgisthang ice must have temporarily blocked the Saser stream. The conformation of the grassy plateau beyond this to the east shows that the next glacier in that direction, now nearly 2,000 feet higher, has previously covered it . . Where glaciers have shrunk the old lateral moraines usually make good walking; but we found evidence of growth, fresh ice and debris invading the hill-side with no definite lateral moraine for some miles' (*Thirty Years in Kashmir*, pp. 260, 261).

I can find no other observations relating to the snout of the Mamostong glacier. In 1926, we found the glacier in practically the same position as that noted by Neve 19 years before, though it seemed to me to be flatter than he describes. This was, however, normal summer ablation. The main stream of the Saser now found a way partly round the foot of the glacier, and was carrying away the debris that constantly fell off the glacier snout. No moraines were noticeable, probably for this reason; but the appearance gave me the impression that it was slowly shrinking in volume.

(*b*) GLACIERS NORTH OF THE MUZTAGH-KARAKORAM RANGE.

THE SHAKSGAM VALLEY.

Three glaciers, the Gasherbrum, the Urdok and the Kyagar, have been observed, and all at the time of observation protruded into or across the main valley of the Shaksgam. There is certainly one, and almost as certainly two glaciers, which project into the Shaksgam valley between the Urdok and the Kyagar. Nothing is known of the western of these. The eastern, which drains the north-

ern slopes of Teram Kangri, seems to extend right across the Shaksgam bed, but no lake appeared to be held up by it in 1926.[1] The most striking feature of all these glaciers is the immense size of the ice-pinnacles, caused by radiation and evaporation in an intensely arid region. A large amount of snow is deposited on the icy Muztagh range, the northern walls of which are clothed in immense accumulations of névé, forming large reservoirs of supply for the glaciers. The beds of these transverse glaciers have very small gradients, which fact, taken in conjunction with the large surface exposed to ablation by radiation and evaporation, probably accounts for their lengths being comparatively short.

There is to my mind no doubt that the whole of the Shaksgam valley was at one time filled with an immense glacier, stretching at least as far as the Urdok snout and probably further (*Records of the Survey of India*, Vol. 22, p. 87 ; the Shaksgam valley is fully described in this volume, chapters vii and ix).

25. Gasherbrum Glacier.

Sheet, 52 A ; *Type*, mainly transverse ; *Length*, 12 miles approximately ; *Height of Snout*, 13,000 feet approximately ; *Fall*, about 6,000 feet in 12 miles (500 feet per mile, 9·5%).

In 1889, Sir Francis Younghusband passed the snout of this glacier, but did not explore it. He saw it again from the ridge between it and the Urdok glacier ; it was once more seen in the distance from the Sella pass in 1909, during the Duke of the Abruzzi's expedition ; and it was passed by a party of the Duke of Spoleto's expedition in 1929. It appears to drain the whole eastern slopes of Broad Peak and the northern face of Gasherbrum III. As yet it is unexplored (*Karakoram and Western Himalaya*, panoramas F and I).

Younghusband found the snout of the glacier protruding right across the valley of the Shaksgam and nearly touching the cliffs on the right bank. Fortunately the river had kept a way for itself by continually washing away the end of the glacier, which terminated in a great wall of ice 150 to 200 feet high. The passage

[1] The glaciers of the Shaksgam form a curious parallel to those of the Shingshal valley. Both valleys contain a glacier near the head (the Kyagar and the Khurdopin) which impound considerable lakes; and the glaciers of both valleys below these dams, though stretching into the river-bed, do not seem to cause dangerous blocks. The counterpart of the Virjerab is, however, absent from the Shaksgam valley.

round the end of the glacier was not unattended with danger, for the stream was swift and strong (*Proceedings, Royal Geographical Society*, Vol. 14, p. 210). From a letter received from a member of the Duke of Spoleto's expedition the glacier seems to have been in approximately the same position in 1929, but details are not yet available (January 1930).

26. Urdok Glacier.

Sheet, 52 A; *Type*, mainly longitudinal, last 4 miles probably transverse; *Length*, 13 miles approximately; *Height of Snout*, 13,100 feet approximately; *Fall*, 154 feet per mile, approximately (2·9%).

Sir Francis Younghusband is the only explorer to visit this glacier, and he traversed it to its head at a height of 17,000 feet. He describes it fully in *Proceedings, Royal Geographical Society*, Vol. 14, pp. 210-212.

He gives the total length as 18 miles, but I find it impossible to fit this in with his sextant latitudes (*Records of the Survey of India*, Vol. 22, pp. 66, 67, 68). If, as I believe, the Workmans reached a col overlooking a head branch of the Urdok, called by them the Indira Col, the length would be little more than 13 miles. It is notoriously difficult to estimate distances in such country as this. The névé consists of a smooth undulating snow-field, about a mile and a half in width. Lower down the névé is split up into crevasses, which increase in size as the glacier is descended. Then the surface is broken up into a mass of typical trans-Muztagh ice domes and pinnacles of pure white ice. On each side lateral moraines appear, and other glaciers join, each with its centre of white ice-peaks and its lateral moraines, preserving each its own distinct course down the valley, until some three miles from the snout the pinnacles are all melted to the glacier level, and the surface presents the appearance of a billowy mass of moraine. Sir Francis recorded that the Urdok glacier extended across the Shaksgam valley.

In 1926, I did not see any part of this glacier, but was able by stereography to survey a portion of its eastern enclosing wall. This wall can be plainly identified in panorama F of De Filippi's *Karakoram and Western Himalaya*, taken from a ridge to the east of the Sella pass.[1] In 1929, a party of the Duke of Spoleto's expedition passed the snout of the glacier, but no details are yet available

[1] *Geographical Journal*, Vol. 75, pp. 168, 169.

(January, 1930), and we do not know whether they crossed the ice or were able to pass up the valley below the snout.

27. Kyagar Glacier.

Sheet, 52 E ; *Type*, transverse ; *Length*, 12 miles ; *Height of Snout*, 15,550 feet ; *Fall*, 220 feet per mile for last 9 miles (4·1%).

This glacier has been observed by the members of my expedition in 1926. A detailed survey of a large portion of it was made by me by stereography on the scale of 1 : 50,000. A reduction of this, on the scale of 1 : 100,000, is published in the *Geographical Journal* for October, 1927 (Vol. 70), and a complete map, incorporating the stereographic map and the planetable survey appears in *Records of the Survey of India*, Vol. 22, together with a detailed description and photographs.

The glacier is supplied from the ice-clad slopes of the Apsarasus group (23,770 feet) of the Muztagh-Karakoram. It has an open névé basin lying under this wall, divided by two large spurs into three heads. Near the snow-line the glacier appears to be intersected by numerous crevasses, but from the junction of the head-branches, the combined ice-stream becomes a tumbled mass of pinnacles, which continue the whole distance of six miles to the snout, which extends right across the Shaksgam valley and is crushed and contorted against the marble cliffs on the right bank of the valley. There is no degeneration of the pinnacles near the snout, as there is with the Urdok glacier, and the surface ice at the end is mostly clear (though there is a lower layer of black ice containing englacial moraine), the walls of the glacier dam being some three hundred feet of sheer ice-cliff. During our visit in July falls of ice-pinnacles near the snout were not uncommon, while floating ice-floes on the dammed-up lake showed that the glacier was very much alive. The snout had, however, spread laterally in the river-bed, and here attained a width of about two miles. Except for the ice-floes, there were no detached pinnacles and from the actual condition of the snout, it did not appear to be retreating. In July, the lake was over two miles in length ; by the end of August it had increased to a little over five miles. Above the previous year's level of the lake, as indicated by the upper line of ice-blocks along the hill-side, there were other lines scratched on the slopes, indicating previous higher levels of the lake. The highest of these

was some 20 feet above the present surface of the glacier, showing that a few years ago the glacier dam must have been higher than it now is. The rocks actually at the snout were polished and rounded for several hundred feet above the present level of the glacier, and I am convinced that at no very distant date this glacier turned down the main valley of the Shaksgam. There are marked lateral moraines on the west bank, and an ablation valley on this side, but only one medial moraine reaches the snout; this moraine maintains its course without spreading and without being encumbered by any continuous area of englacial moraine coming to the surface, though at the base of the pinnacles patches of moraine debris were common. In the lower reaches true crevasses were the exception, and surface lakes were common, owing to the gentle fall.

The glacier snout was reached by a small party of the Duke of Spoleto's expedition of 1929, from down-stream. It appears to have been in much the same condition as when I discovered it in 1926. The valley was entirely blocked by it and the party made no attempt to cross.

No definite conclusions are possible, as the present conditions of the surface ice and snout, which might lead one to expect that the glacier was advancing, seem to be contradictory to the evidence of the slopes above the lake. I believe that if this glacier definitely retreats from the Shaksgam bed, it would be suitable for the measurement of secular movement, owing to its gentle fall and large névé area, which must rule out accidental movements.

THE SHYOK VALLEY.

28. Rimo Glacier.

(a) NORTH BRANCH.

Sheet, 52 E; *Type*, transverse; *Length*, 25 miles; *Height of Snout*, 16,350 feet; *Fall*, 134 feet per mile (2·5%).

(b) SOUTH BRANCH

Sheet, 52 E; *Type*, transverse; *Length*, 15 miles; *Height of Snout*, 16,350 feet, *Fall*, 223 feet per mile (4·2%).

1869. Robert Shaw, the first Englishman to visit Kashgar from India, gives a very vivid description of the view of this glacier in '*High Tartary, Kashgar and Yarkand*,' p. 432. He seems to have been the only traveller till recent years to realize its size.

1914. Sir F. De Filippi explored the whole glacier. The Rimo is divided into two main branches, which descend in gentle slopes from their respective valleys to the north and west and join almost at right-angles, two miles from the combined snout, which fills the valley from side to side with a width of 2 miles. Their line of junction is sharply defined by a wide medial moraine, which forms the easiest approach through the ice pinnacles of the lower reaches of both branches. These pinnacles continue up the northern branch for a distance of from 8 to 10 miles when they are replaced by gentle transverse undulations. Just beyond this point the northern branch is joined by a wide tributary entering from the north, which throws an arm of ice over the Central Asian watershed, and forms the main glacier source of the Yarkand river (see Yarkand-Rimo glacier, No. 32 below). This branch is fed by a basin from the west.

The main trunk of the Rimo, now the central of three ice-streams, continues for another 10 miles, beyond the junction, with a gentle slope to the snow-line at a little over 18,000 feet. Here the slope becomes rapidly steeper as it leads to the upper basin. The glacier fills this basin to the brim and overflows between low peaks. Its most distant head leads by a gentle saddle to the Teram Shehr branch of the Siachen glacier.

The southern branch is steeper, and less complicated. Its upper basin lies close under the steep north-eastern wall of the Muztagh-Karakoram, and is fed by eight large tributaries descending from high and distant saddles. The highest peak at the head of this branch is Pk. 50, 24,230 feet (De Filippi, *Geographical Journal*, Vol. 46, pp. 93 and 99; Wood, *Explorations in the Eastern Karakoram*, pp. 5, 6). De Filippi's survey of the Rimo glacier on the scale of 1: 100,000 is shown on his map, *Il Ghiacciaio Rimu*; published in 1920 by the *Instituto Geografico Militare* of Florence. Terminal moraines are shown at the immediate snout.

1928. The snout of this glacier was visited by Mr. F. Ludlow, but there is no indication in his report (*Himalayan Journal*, Vol. I, p. 6) as to whether the glacier is advancing or retreating. Photographs, copies of which he has deposited with the Himalayan Club, undoubtedly show terminal moraines of considerable size east of the glacier snout.

1929. Mr. J. P. Gunn, who visited the snout of the Rimo in August, noted 'two small gravel ridges' in front of the tongue, but he records definitely that there were no dead pinnacles and he

saw 'no general signs of retreat' (*Report on the Chong Kumdan Dam and the Shyok Flood of 1929*, in the press, January, 1930).

Conclusion.—The terminal moraines found by De Filippi in 1914, by Ludlow in 1928 and by Gunn in 1929, give indications of retreat, and, owing to the low fall of the glacier bed, such retreat is not likely to be much affected by periodic, seasonal or accidental factors. I consider that these are signs of slow secular retreat, but they are not conclusive.

29. Chong Kumdan Glacier.

Sheet, 52 E ; *Type*, transverse ; *Length*, 12 miles, including snow lake ; *Height of Snout*, 15,470 feet ; *Fall*, 353 feet per mile (6·6%).

This glacier has never been actually explored, but, owing to the fact that the Central Asian trade-route passes up the Shyok valley by its snout, we probably have more definite knowledge of its snout movements than of those of any other glacier in the Himalaya.

It was not, however, till De Filippi's expedition of 1914 that the glacier was surveyed even from a distance and there was even then doubt as to its source, which was shown tentatively as extending north of the Mamostong glacier. Dr. Arthur Neve, however, from the high col at the head of the Mamostong in 1907, saw a great glacier stretching far away to the north which he thought must join the Rimo glacier (*Thirty Years in Kashmir*, p. 265). From preliminary accounts of the Visser expedition of 1929 I understand that the area immediately north of the Mamostong is filled by a great 'snow lake,' somewhat similar to, though smaller than, that at the head of the Biafo glacier (No. 22). This lake forms an immense reservoir of ice above the snow-line and so magnifies the effects of snow precipitation. The apparent periodicity of the snout of this glacier is of very great interest.

Below is given a summary of observations of the snout of the Chong Kumdan glacier (*Himalayan Journal*, Vol. I, p. 22, S. 99).

About 1780. Slight evidence of a glacier burst.

1812. Mir Izzet Ullah passed up the valley and records that the glacier was on his left hand. (*Travels beyond the Himalaya*, trans. in Journ. A.S.B., Vol. 7, 1842-43, p. 297.)

1812-24. Snout probably clear of Shyok river.

1824. Snout about ½ mile from eastern wall of valley (Henry Strachey, *Physical Geography of Western Tibet*, p. 56).

1835. In June, 1835, the dam, caused by the ice advancing across the river, burst. It is not known how long the dam had been in existence (*Physical Geography*, p. 55). For a discussion on the date see footnote 5, *Himalayan Journal*, Vol. I, p. 23.

1839. Another cataclysm occurred owing to the reforming of the glacier dam (*Physical Geography*, p. 57).

1842. A third burst, apparently of less extent than the previous two (*Geographical Journal*, Vol. 35, p. 647).

1855. Capt. Henderson apparently found this glacier projecting into the Shyok river.

1862. Mr. E. C. Ryall's planetable (Survey of India) showed the Chong Kumdan glacier as closing the route, but not blocking the river.

1864. Mr. W. H. Johnson, Survey of India, crossed the Depsang plains in summer: an indication that the Shyok river was blocked.

1865. Johnson passed down the valley in winter: possibly on the river ice (*Johnson's Itineraries*, in old Survey of India report).

1869. Robert Shaw returned from Kashgaria down the valley. The Chong Kumdan projected into the Shyok and compelled him to ford the river.

1873. Gordon and other members of the Forsyth Mission passed the snout of this glacier. He writes: 'It shoots down from a lateral valley to the north-west and almost touches the opposite side of the valley. It probably at one time formed a long and extensive shallow lake above' (*The Roof of the World*, p. 8 and illustration).

1889. Sir Francis Younghusband travelled by the Depsang route, the valley route being apparently impassable (*The Heart of a Continent*, p. 225).

1894. Church and Phelps passed up the valley below the snout.

1902. In April, Sven Hedin passed the snout on the river ice below it. The glacier was about 30 to 40 metres from the diminished river (*Scientific Results of a Journey in Central Asia*, Vol. iv, p. 410, with photographs; *Geographical Journal*, Vol. 36, 1910, p. 186).

1909. Longstaff's map shows the Chong Kumdan as leaving a passage for the river. He writes: 'Its snouts projected far into the river, but we were unable to see whether any part of it reached the further bank' (*Geographical Journal*, Vol. 35, p. 641).

1914. De Filippi's map and Wood's survey show the Chong Kumdan as reaching the Shyok river bank, but the river itself is shown as passing the foot of the snout.

1919-1925. I was told that the valley route had been open for six years prior to 1925.

1925. The Roosevelts in June, found the Chong Kumdan glacier 'stretched across the entire valley', and were forced to return and take the Depsang route.

1926. In June, the valley was reported to me as blocked by the Chong Kumdan, behind which a lake had formed, and I had to take the Depsang route. The dam burst at the end of October and a bad flood occurred owing to the liberation of the lake.

1928. The dam reformed during the winter of 1926-27 (*Geographical Journal*, Vol. 74, p. 384). Ludlow, in August, 1928, found the Shyok river completely dammed by the Chong Kumdan glacier; its snout had spread down the main valley for a distance of 500-600 yards. The dam rose steeply for this distance and was covered with debris (*Himalayan Journal*, Vol. 1, pp. 9, 28).

1929. The valley was still blocked by the same glacier, which burst at 5 a.m. on August 15th. According to Gunn, the break resulted in a channel, 400 feet wide, starting from near the right bank of the valley upstream of the dam, and emerging at the left bank on the downstream side (*Report on the Chong Kumdan Dam and the Shyok Flood of 1929*; see also *Himalayan Journal*, Vol. 2).

Conclusion.—As already mentioned, this glacier has a large snow reservoir at its head, which should tend to exaggerate periodic fluctuation at the expense of secular, seasonal and accidental movement. We find a definite period of valley blocking from about 1834 to 1842, since when there is no definite block reported until the present day. The present period of blocking has lasted from 1925 to date. Minor fluctuations between these periods may possibly be accounted for by seasonal factors. If the course of the first block be repeated, we may expect the valley to be blocked again during the present winter (1929-1930), and another glacier burst may occur in 1931, after which there should be a period of retreat. These movements are undoubtedly almost entirely periodic, the total definite periodicity being apparently about 90 years between the years of maximum advance. Unfortunately we have a distinct gap in our observations during the period from 1873 to 1889, during which time there seems to have been a period of advance. In 1873, Colonel Gordon reported the glacier almost to touch the opposite side of the valley, and I can find no record of any traveller having passed up the valley for the next 20 years. About the middle of August, 1879, the Indus recorded an abnormal rise very similar to

that caused by the Shyok Flood of 1929; and on the 29th July, 1882, there was another abnormal flood, this time giving a record rise at Attock five feet higher than the 1929 one. These two high floods have not been explained, and were far greater than any rise before or since for many years. There is every likelihood of there having been blocks formed by the Chong Kumdan dam about this time, as may be clearly seen from the chart illustrating the snout position. I feel convinced that these two floods, of 1879 and 1882, were caused by the bursting of the Chong Kumdan dam during the last period of glacier advance. If this is so, the periodicity would be approximately 45 years.

There is very slender evidence of a previous burst about 70 years prior to 1848, based on the memory of one old woman. If for 70 we could substitute 56, which would more likely be within her memory, this would fit in with our cycle of 45 years.

Forecast.—From an examination of all the evidence and from a study of Gunn's report on the condition of the dam in 1929, both before and after the flood, I believe that a period of retreat is about to begin; but the normal seasonal advance during winter will probably close the present channel, and there may be one more flood, though not of much consequence, possibly in August, 1931. After that year there will be no danger till about 1969, when a further series of blocks may be expected to commence and to last till 1977.

30. Kichik Kumdan Glacier.

Sheet, 52 E; *Type*, Transverse; *Length*, 7 miles; *Height of Snout*, 15,250; *Fall*, 500 feet per mile (9·5%).

The evidence of the Kichik Kumdan movements is not so easy to sift as that of the Chong Kumdan. We know little about its basin, and the present map is based only on a rough reconnaissance sketch made in 1914. It is believed to have a fairly large ratio of supply area to melting area. The following observations give a general summary of what is known.

1824. Snout clear of the Shyok river and about half a mile distant from the eastern wall of the main valley (*Physical Geography of Western Tibet*, p. 56).

1848. Thomas Thomson recorded that he found the Kichik Kumdan glacier impossible to cross. He writes: 'At the bottom of the valley it spread out in a fan-shaped manner to a width of at least a mile; perhaps indeed much more, for as I failed in getting

round it, I was unable to ascertain precisely.' He found that at its south-east corner it was nearly a hundred yards from the river, and here was its true snout from which issued a considerable stream. Further on he found the glacier 'fairly projecting into the Shyok in such a manner that I could not see anything of what lay beyond.' The terminal cliff varied from fifteen to thirty feet (*Western Himalaya and Tibet*, pp. 420, 440 *sqq.*).

1855. Captain Henderson found the glacier projecting into the Shyok in August (*Journ. A. S. B.*, Vol. 28, 1859, p. 222).

1862. E. C. Ryall of the Survey of India showed the glacier half a mile back from the river on his planetable.

1869. R. B. Shaw in July, found the Kichik Kumdan glacier completely blocking the road, having advanced since April when one of his guides had passed the snout by the river-bed. Shaw found the ice of the glacier right up to the cliffs on the left bank of the Shyok, the river forcing its way through tunnels under the ice (*High Tartary, Yarkand, and Kashgar*, p. 433).

1873. Gordon and others of the Forsyth Mission made their way round the snout of the Kichik Kumdan glacier. He writes: 'The end of the glacier continues down the right bank of the stream' (*i.e.* the Shyok) 'for over two miles, forming a perfect wall of ice rising from the water about 120 feet, and showing a surface covered with countless pinnacles and points. Portions of it still stand at several places on the opposite bank, where the original mass was forced against the great up-rising red cliffs, and blocked the stream, thus forming a lake, which at last burst this ice-barrier by the increasing pressure of the collected waters' (*The Roof of the World*, pp. 17, 18 and frontispiece).

1894. Church and Phelps passed up the valley below the snout.

1899. The British Joint Commissioner commenced building a road along the valley. Progress was arrested by the advance of the Kichik Kumdan glacier. Traders, however, continued to pass round the snout in winter-time, up to the winter of 1902-03.

1902. Sven Hedin in April, passed the snout of the glacier on the river ice. It was stretching almost to the cliffs across the river, and there was only a narrow passage 10 metres wide near the cliffs (*Scientific Results of a Journey in Central Asia*, Vol. 4, p. 410).

1903. A flood occurred in the Shyok, attributed by the Joint Commissioner to the bursting of the Kichik Kumdan dam (*Geographical Journal*, Vol. 35, p. 641).

1908. Sir Aurel Stein took the Depsang route and there is therefore some slight evidence that this glacier was then blocking the river since the Chong Kumdan was clear (*Ruins of Desert Cathay*, Vol. ii, p. 486).

1909. Longstaff shows on his map the Kichik Kumdan glacier right across the river-bed leaving no passage for the river. No lake, however, is shown upstream of the glacier, and none is mentioned in his report.

1914. Neither De Filippi's nor Wood's maps show this glacier. But Wood mentions in his report that in June, he sent Shib Lal of the Survey of India back from the Depsang plains to carry out a survey of the route up the Shyok. He found the Kumdan glaciers blocking the river and was unable to cross them. Since the Chong Kumdan did not then block the river, presumably he refers to the Kichik (*Explorations in the Eastern Karakoram*, p. 7).

1925. The Roosevelts in June, passed the snout with some difficulty, which shows that the valley was not blocked at this point (*East of the Sun and West of the Moon*, pp. 59-61).

1928. Ludlow found the Kichik Kumdan ice-pinnacles more than a hundred yards from the river bank in August, and his photographs clearly show that his belief that the glacier was retreating at that time is correct. The ice also was most certainly decreasing in volume near the snout.

1929. Gunn, in August, before the bursting of the Chong Kumdan dam, found no traces of terminal moraine, but reported that the terminal ice-pinnacles were now about 800 yards from the *cliffs* on the left bank, and much diminished in size.

Conclusion.—Owing to the powerful erosion exerted by the Shyok river, it is not easy to define the exact periodicity of this glacier. It seems to have been liable to block the main river during the periods 1857-69 and 1902-14. These figures give danger periods of 12 years with safe-periods of 33 years, the periodicity being 45 years as in the case of the Chong Kumdan, though the actual time of maximum advance is entirely different.

There is only one recorded flood from the Kichik Kumdan, in 1903, and it does not appear to have done a great amount of damage. This is accounted for by the fact that (to use Gunn's words): 'the configuration of the country is such that, even if it did impound a four-hundred-foot depth of water, the volume of the lake would

only be about one-third of the volume retained by the same depth at the Chong Kumdan.'

Forecast.—The next block period will commence probably about 1947. But it will be of little consequence. If it impounds a lake and then bursts, the damage will be inconsiderable.

31. Aktash Glacier.

Sheet, 52 E ; *Type,* Transverse ; *Length,* 5 miles ; *Height of Snout,* 15,000 feet : *Fall,* 400 feet per mile (7·5%).

Observations of this glacier are much less reliable than those of the two preceding ones. We know little of its basin, but it seems to be compound, two main branches joining near the snout. We are not, therefore, likely to obtain exact information regarding periodicity from the rough observations we possess. These are summarized below :—

1848. Thomas Thomson found the Aktash glacier extending across the Shyok river, which flowed out from beneath the ice. The ice, however, did not extend to the foot of the precipice on the left bank of the Shyok, as far as he could see. He noted the ancient moraine, 'deposited at a period when the glacier must have been more bulky than it now is' (*Western Himalaya and Tibet,* pp. 420, 440).

1855. Henderson found the glacier projecting into the Shyok valley.

1862. Ryall showed the Aktash glacier one mile back from the river-bed.

1869. Shaw, who gives careful details of both the Kumdan glaciers, does not mention the Aktash. We may therefore assume that in this year it was well away from the river.

1873. Gordon also, though he describes the Kumdan glaciers, makes no mention of the Aktash.

1902. Sven Hedin found the Aktash glacier well clear of the road.

1905. The Aktash glacier advanced across the river-bed, but the river forced a passage under the ice.

1909. Longstaff shows the Aktash glacier right across the river on his map in *Geographical Journal,* Vol. 35. Sven Hedin considered that there had been a considerable advance of this glacier since 1902.

1914. The Aktash was apparently clear of the river.

1925. The Roosevelts passed the snout of the glacier.

1928. Ludlow found the terminal ice-pinnacles of the Aktash glacier, except at one spot, 200 yards or more from the river. He doubted whether the glacier ever completely blocked the Shyok. There was no indication of a lake in the past, and Ludlow considered the bed was sufficiently sandy and porous to allow drainage under the ice as seems to have happened in 1848 and 1905.

1929. Gunn considered that the snout had been retreating since the Chong Kumdan flood of 1926 (*Report of the Chong Kumdan Dam and Shyok Flood of 1929*).

Conclusion.--The movements are mainly periodic, and the periodicity seems to be approximately 55 years. Observations for periodic movement are undoubtedly affected by the variations in the two large glaciers further up the Shyok, and there is certainly a variable amount of end-erosion. In 1928 and 1929 the glacier seemed to be definitely retreating. No secular conclusions can be drawn.

Forecast.--The next period of maximum advance should commence about 1960 and should last from 4 to 5 years. There appears to be no danger of glacier bursts from this glacier.

THE YARKAND VALLEY.

32. Yarkand Rimo Glacier.

Sheet, 52 E : *Type,* Saddle, compound : *Length,* including longitudinal head basin, 12 miles ; *Height of Snout,* 17,100 feet : *Fall,* 143 feet per mile in longitudinal head (2·7%) : 226 feet per mile in last 2½ miles (4·3%) ; *total fall,* 160 feet per mile (3·0%).

This glacier may be examined from two points of view. It may be considered as a small tongue thrown over the Central Asian watershed, or it may be looked on as the main end of a longitudinal basin, of which another tongue joins the Shyok Rimo (north branch). We have few observations and unfortunately I did not realize in 1926 the importance of examining the snout of this glacier carefully.

From a comparison between a photograph taken by me on 1st July, 1926, with that shown in *Geographical Journal,* Vol. 46, p. 95, taken in 1915, I am inclined to think that there has been little change. The same barren rock is visible to the west of the snout in both photographs, while in 1926 there appeared to be a small terminal moraine forming.

There is, however, too little information as yet from which to draw conclusions, though I believe exact observations would give valuable information of the periodic motion caused by the large supply basin, since the area for seasonal or accidental change is small.

THE LUNGMO-CHHE VALLEY.

Two glaciers reach the valley of the Lungmo-chhe tributary of the Yarkand river (the valley 'I' of Wood). They descend through comparatively narrow valleys from large névé basins, surrounded by ice-clad peaks rising to 22,000 feet. They seem to be very suitable for periodic snout measurement, though their pinnacled snouts leave the actual end difficult to determine, owing to the dead pinnacles during retreat.

33. Glacier 'A', Lungmo-chhe.

Sheet, 52 E; *Type,* Longitudinal; *Length,* 7 miles; *Height of Snout,* 16,480 feet; *Fall,* 430 feet per mile (8·1%).

1914. Wood found that this glacier entirely dammed the stream-bed, spreading across the valley bottom, with its snout resting against a rocky cliff on the left bank. He considered that from the evidence of its moraines it had once been of greater extent (*Explorations in the Eastern Karakoram*, etc., pp. 17, 18).

1926. I found that this glacier had retreated at least 100 yards, leaving isolated pinnacles of dead ice near the right bank, washed by the river. For another hundred yards or so the glacier was composed of dead pinnacles, between which a passage could easily be threaded without walking on ice (*Records of the Survey of India*, Vol. 22, p. 88).

1927. Gregson visited this glacier and photographed the snout. There appeared to be little difference in the previous nine months, though the dead pinnacles were perhaps more marked and more detached. The nearest pinnacles to the river were still at the edge of the river-bed.

Conclusion.—Marked periodic movement is to be observed in this glacier, as might be expected. Observations unfortunately are likely to be few and far between owing to its inaccessibility.

34. Glacier 'B', Lungmo-chhe.

Sheet, 52 E; *Type,* Longitudinal; *Length,* 9 miles; *Height of Snout,* 16,500 feet; *Fall,* 220 feet per mile (4·1%).

1914. Wood found that this glacier did not stretch entirely across the valley and the way was not blocked. He concluded, however, that it had previously extended right across the valley, and found that its terminal moraine formed a dam, through which the stream had cut a passage. The lake, created by the dam, was gradually silting up (*Explorations in the Eastern Karakoram*, etc., p. 17).

1926. I found little change, though perhaps there was a slight retreat. The river appeared to have scoured a wider passage through the moraine dam, and the snout was definitely clear of the river bank.

Conclusion.—Neither Wood's observations nor mine are sufficiently detailed to draw any certain conclusions. The glacier, however, seems to be undergoing slight periodic retreat.

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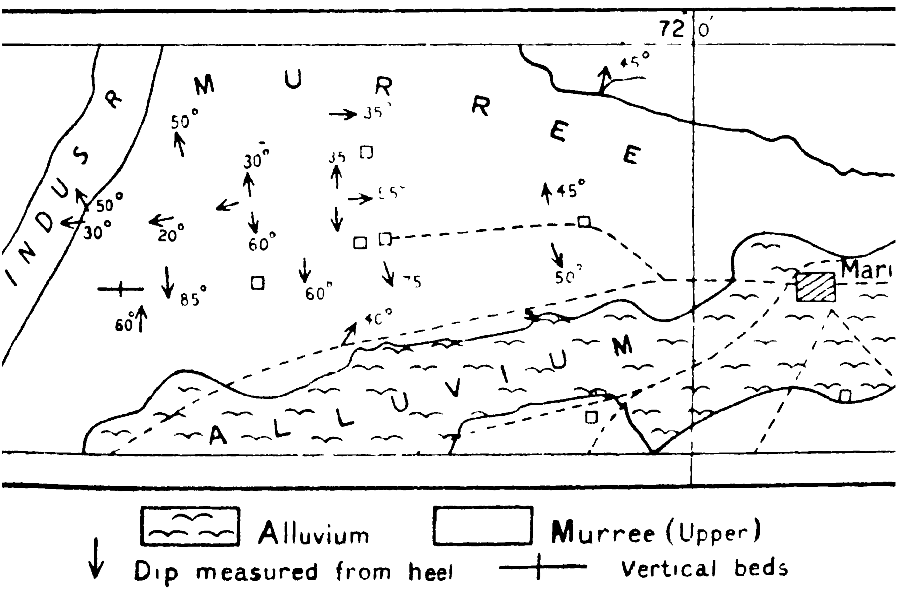
MISCELLANEOUS NOTE.

On the occurrence of a small dome near Mari in the Attock district.

The object of this note is to place on record the occurrence of a small dome in Upper Murree beds on the left bank of the Indus river, about 1½ miles to the west of Mari (33° 31′ 30″ ; 72° 0′ 30″) in the Pindigheb *tahsil* of the Attock district. The dome was mapped by the writer in the course of his field-work during the winter of 1928. The rocks occupying the dome consist of the usual greenish and pepper-and-salt sandstones and purple shales of the Upper Murree type.

The fold is an asymmetric anticline the axis of which is directed roughly E-W. The beds on the northern flank of the anticline have an average dip of 35° N., while the dips on the south are about 60° S. near the crest, but steepen rapidly southwards and only about 300 yards from the crest the beds are almost vertical. Further to the south the beds are seen to have a general northerly dip. Northwards from the crest also the dips are seen to vary both in direction and amount. The fold-axis pitches abruptly eastwards at about 60°, but towards the west the pitch is gentler, being 20° near the dome centre but increasing to 30° further to the west.



SCALE 1″=1 m.

Sketch map showing position of dome near Mari.

Although the geological structure is favourable for the accumulation of petroleum, the small extent of the area covered by the dome and the steepness of beds on its south and eastern flanks tend to preclude the possibility of the existence of any workable chambers underneath.

It deserves mention, in this connection, that according to Sir Edwin Pascoe,[1] the Burmah Oil Company took out a prospecting license over about ½ square mile, 1½ miles from Mari in the Pindigheb *tahsil*. Although it is not possible to ascertain the exact location of this area from the short account given, it does not seem unlikely that it is the same as the dome-area described above.

[1] *Mem. Geol. Surv. Ind.*, Vol. XL, p. 409.

H. M. LAHIRI.

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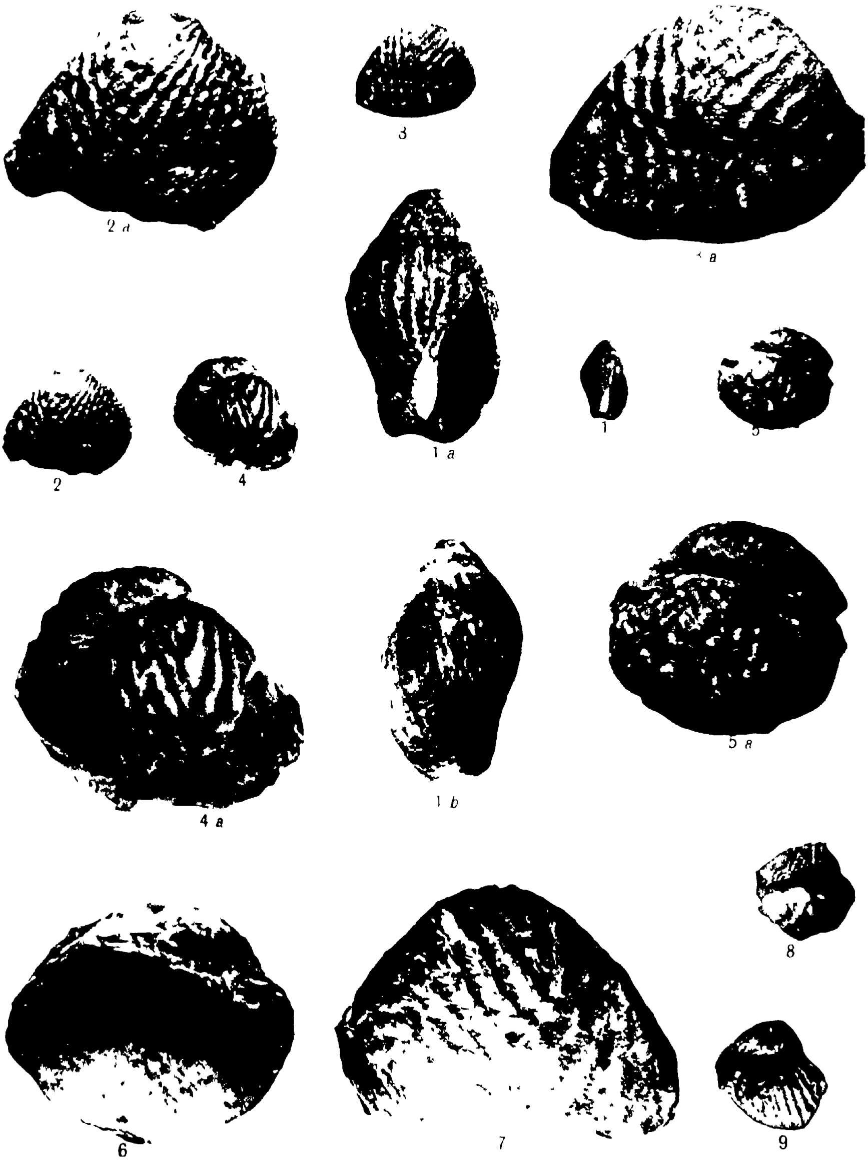

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PEGU FOSSILS, BURMA

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 3.] 1930. [September

THE MINERAL PRODUCTION OF INDIA DURING 1929. BY L. Leigh FERMOR, O.B.E., A.R.S.M., D.SC. F.G.S., F.A.S.B., M. INST. M.M., *Offg. Director, Geological Survey of India.*

CONTENTS.

I.—INTRODUCTION.

THE method of classification adopted in the first Review of Mineral Production published in these *Records* (Vol. XXXII, 1905), although admittedly not entirely satisfactory, is still the best that can be devised under present conditions. As the methods of collecting the returns become more precise, and the machinery employed for the purpose more efficient, the number of minerals included in Class I—for which approximately trustworthy annual returns are available—increases, and it is hoped that the minerals of Class II—for which regularly recurring and full particulars cannot be procured—will in time be reduced to a very small number.

In the case of minerals still exploited chiefly by primitive Indian methods, and thus forming the basis of an industry carried on by a large number of persons each working independently and on a very small scale, the collection of reliable statistics is impossible; the total error from year to year, however, is characterised by some degree of constancy, and the figures obtained may be accepted as a fairly reliable index to the general trend of the industry. In the case of gold, the small indigenous alluvial industry contributes such an insignificant portion to the total outturn that the error from this source may be regarded as negligible.

The average value of the Indian rupee during the year 1929 was 1*s*. 5$\frac{7}{8}$*d*; the highest value reached was 1*s*. 6$\frac{1}{32}$*d*. and the lowest 1*s*. 5$\frac{3}{4}$*d*. The values for 1929 shown in the tables are given on the basis of 1*s*. 5$\frac{7}{8}$*d*. to the rupee; for ease of calculation, £1 has been taken to be equivalent to Rs. 13·4, instead of Rs. 13·42.

Table 1 shows the total value of minerals for which returns of production are available for the years 1929. The average figure for the quinquennium, 1919-23, was £25,194,123. In the following year, 1924, there was an apparent increase of over £3,500,000; this was, in part, however, due to the higher average value of the rupee during that year. Since 1924, there has been a steady decline which has persisted down to the year 1928, for which the value was £21,888,528. 1929 shows an increase in total value amounting to some £533,000, or about 2·4 per cent. over that of 1928. An increase or decrease in value does not always correspond to a similar variation in output, and cannot, therefore, be regarded as an infallible indication of the state of an industry. But in 1929 in almost all cases an increase of value accompanied an increase of production. It must be understood that the figures of Table 1 are value figures, and that a decrease does not necessarily mean a reduced output or a decline in the industry. For instance in the manganese industry there was a small increase in output in spite of a heavy fall in value.

The number of mineral concessions granted during the year under review amounted to 457, against 497 in the preceding year. Of these, 1 was an exploring license, 16 were quarry leases, 338 were prospecting licenses, 102 were mining leases. This small decline follows the enormous drop reported in the previous review, which was taken as indicating a regrettable decline in prospecting and private geological enterprise in the country.

TABLE 1.—*Total value of Minerals for which returns of production are available for the years 1928 and 1929.*

——	1928 (£1= Rs. 13·4).	1929 (£1= Rs. 13·4).	Increase.	Decrease.	Variation per cent.
	£	£	£	£	
Coal	6,604,106	6,668,591	64,485	..	+0·9
Petroleum	4,314,207	4,800,448	486,241	..	+11·3
Lead and lead-ore (*a*)	1,642,036	1,845,641	203,605	..	+12·4
Manganese-ore (*b*)	2,198,895	1,571,030	..	627,865	—28·5
Gold	1,588,252	1,542,109	..	46,143	—2·9
Building materials	1,110,907	1,121,032	10,125	..	+0·9
Salt	745,895	844,400	98,505	..	+13·2
Silver	892,460	802,734	..	89,726	—10·0
Mica (*c*)	698,130	784,092	85,962	..	+12·3
Zinc concentrates (*c*)	553,051	507,532	..	45,519	—8·2
Iron-ore	413,060	484,420	71,360	..	+17·3
Tin-ore	338,895	447,567	108,672	..	+32·0
Copper-ore and matte	372,202	483,529	111,327	..	+29·9
Tungsten-ore	22,354	113,193	90,839	..	+406·4
Saltpetre (*c*)	74,629	71,720	..	2,909	—3·9
Chromite	57,139	62,818	5,679	..	+9·9
Nickel-speiss	39,922	47,670	7,748	..	+19·4
Clays	31,655	40,636	8,981	..	+28·4
Jadeite (*c*)	43,468	36,280	..	7,188	—16·5
Ilmenite	41,557	28,602	..	12,955	—31·2
Antimonial lead	23,658	25,157	1,499	..	+6·3
Steatite	9,706	20,633	10,927	..	+112·6
Ruby, sapphire and spinel.	13,247	13,564	317	..	+2·4
Zircon	4,267	10,805	6,538	..	+153·4
Magnesite	11,969	9,640	..	2,329	—19·5
Gypsum	10,919	8,784	..	2,135	—19·5
Refractory materials	6,360	7,203	843	..	+13·2
Bauxite	7,034	5,399	..	1,635	—23·2
Ochre	3,953	4,095	142	..	+3·6
Diamonds	4,887	3,884	..	1,003	—20·5
Fuller's earth	1,852	1,917	65	..	+3·5
Monazite	1,242	1,800	558	..	+44·9
Barytes	1,463	1,697	234	..	+16·0
Asbestos	1,622	1,206	..	416	—25·6
Agate	..	597	597	..	+100·0
Amber	897	454	..	443	—49·4
Alum	412	..	..	412	—100·0
Corundum	207	304	97	..	+46·8
Garnet	90	..	..	90	—100·0
Graphite	..	87	87	..	+100·0
Antimony-ore	769	74	..	695	—90·5
Soda	44	44	..	..	..
Bismuth	20	23	3	..	+15·0
Apatite	1,081	15	..	1,066	—98·6
Serpentine	6	6	..	..	..
Borax	2	2	..	..	..
Copperas	1	..	..	1	—100·0
TOTAL	**21,888,528**	**22,421,434**	**1,375,436**	**842,530**	**+2·4**
			$\underbrace{\qquad\qquad}_{+532,906}$		

(*a*) Excludes value of antimonial lead. (*b*) **Export f.o.b.values.**
(*c*) Export values.

II.—MINERALS OF GROUP I.

Antimony.

The production of antimonial lead obtained as a bye-product in the lead refinery at the Namtu smelter of the Burma Corporation, Limited, decreased slightly from 1,241 tons valued at Rs. 3,17,011 (£23,658) in 1928 to 1,200 tons valued at Rs. 3,37,101 (£25,157) in 1929. This product contains approximately 77 per cent. of lead, 21 per cent. of antimony and from 6 to 8 ozs. of silver to the ton, and is exported to the United States of America for further treatment.

A small quantity of antimony-ore is also produced in the Amherst district, Burma. The output in 1929 amounted to 77 tons valued at Rs. 988 (£74) against 370 tons valued at Rs. 10,300 (£769) in the previous year.

Chromite.

There was an increase in the production of chromite in India during 1929, amounting to 4,110 tons, for which the deposits in Baluchistan and Singhbhum were chiefly responsible. The total exports from India during the year were, however, much below the production, amounting to 32,302 tons. Chromite exported from the ports in British India amounted to 18,059 tons against 31,209 tons in 1928. Chromite mined in British India is also exported from the port of Mormugao in Portuguese India; the quantities exported from that port during 1929 and 1928 were 14,243 tons and 14,099 tons, respectively. The increase in production was accompanied by a slight rise in the value per ton to Rs. 17·0 from Rs. 16·8 in 1928.

Something like half the world's supplies of chromite comes from Southern Rhodesia, which has now become the predominant source of this mineral.

TABLE 2.—*Quantity and value of Chromite produced in India during the years 1928 and 1929.*

—	1928.			1929.		
	Quantity.	Value (£1=Rs. 13·4).		Quantity.	Value (£1=Rs. 13·4.)	
	Tons.	Rs.	£	Tons.	Rs.	£
Baluchistan—						
Zhob . .	15,002	2,25,030	16,793	17,905	2,66,761	19,908
Bihar and Orissa—						
Singhbhum .	2,165	48,949	3,653	3,149	68,440	5,107
Mysore State—						
Hassan .	23,639	3,86,008	28,806	22,799	3,71,936	27,756
Mysore .	4,649	1,05,681	7,887	5,712	1,34,632	10,047
Total .	**45,455**	*7,65,668*	*57,139*	**49,565**	*8,41,769*	*62,818*

Coal.

There was an increase during the year of 875,862 tons, or about 3·9 per cent., in the output of coal. This increase was due chiefly to Bengal, Bihar and Orissa, and the Central Provinces, and, to a decreasing extent, to Hyderabad, Assam, and Rajputana. There was a decrease in the production of Baluchistan, Central India, and the Punjab. The increase in Bihar and Orissa was mostly from Jharia, Bokaro, and Karanpura. Bokaro now produces 9 per cent. of the Indian total. Giridih decreased her raisings by nearly 33,000 tons. Karanpura, on the other hand, made another stride from 390,493 tons in 1928 to 467,127 tons in 1929. Jharia showed another small proportionate increase of some 120,000 tons, but was still well below her peak output of 1919. Talcher continued her upward movement with an increase of over 9,000 tons. There was a slight recovery on the part of Rampur, which was more than set off by the decline in the case of Jainti. The Raniganj field showed the largest increase, nearly 368,000 tons. In Central India there was an increase in the output from Umaria, which was more than counter-balanced by a decrease in the case of Sohagpur. In the Central Provinces there was another substantial increase in the output from the Pench Valley, as also from Ballarpur. In Hyderabad, both the Singareni and Sasti fields were responsible for marked increases.

The statistical position at the end of the year showed a very great improvement in spite of the increase in the total output.

Stocks in the six provinces of Assam, Baluchistan, Bengal, Bihar and Orissa, the Central Provinces, and the Punjab, for which such figures are available, showed a total reduction of 781,477 tons, as is seen from the following data :—

Year.	Opening stock.	Closing stock.	Reduction during year.
	Tons.	Tons.	Tons.
1927	2,161,806	1,721,288	440,518
1928	1,721,288	1,625,717	95,571
1929	1,625,717	844,240	781,477

The increased output of 3·9 per cent. was accompanied by a slight increase in the total value of the coal produced in India from Rs. 8,84,95,027 (£6,604,106) in 1928 to Rs. 8,93,59,124 (£6,668,591).

There was again a reduction in the pit's mouth value per ton of coal for India as a whole, but only from Rs. 3-14-10 to Rs. 3-13-6 —a fall of Rs. 0-1-4 —, and all provinces participated in this fall, with the exception of the Central Provinces for which the rise was 11 pies only. In the two great coal provinces, Bihar and Orissa and Bengal, the value dropped by Rs. 0-1-8 and Rs. 0-2-5 respectively. In Assam it fell by Rs. 0-1-6 ; in Central India the fall was Rs. 0-0-6, in Hyderabad Rs. 0-6-0, and in the Punjab Rs. 0-0-2.

TABLE 3.—*Provincial production of Coal during the years 1928 and 1929.*

Province.	1928.	1929.	Increase.	Decrease.
	Tons.	Tons.	Tons.	Tons.
Assam	298,089	322,515	24,426	..
Baluchistan	17,931	16,222	..	1,709
Bengal	5,639,993	5,965,104	325,111	..
Bihar and Orissa . . .	14,827,453	15,133,144	305,691	..
Central India	218,750	205,132	..	13,618
Central Provinces . . .	732,353	882,331	149,978	..
Hyderabad	734,765	815,875	81,110	..
Punjab	46,152	43,136	..	3,016
Rajputana	27,386	35,275	7,889	..
Total .	*22,542,872*	*23,418,734*	*894,205*	*18,343*

TABLE 4.—*Value of Coal produced in India during the years 1928 and 1929.*

—	1928.			1929.		
	Value (£1 = Rs. 13·4).		Value per ton.	Value (£1 = Rs. 13·4).		Value per ton.
	Rs.	£	Rs. A. P.	Rs.	£	Rs. A. P.
Assam	88,04,662	283,930	12 12 2	40,85,704	304,903	12 10 8
Baluchistan . . .	1,63,959	12,236	9 2 4	1,43,039	10,675	8 13 1
Bengal	2,24,34,052	1,674,183	3 15 8	2 28,49,786	1,705,208	3 13 3
Bihar and Orissa . .	5,42,11,122	4,045,606	3 10 6	5,37,64,328	4,012,263	3 8 10
Central India . .	8,47,939	63,279	3 14 0	7,88,192	58,820	3 13 6
Central Provinces . .	30,81,627	229,972	4 3 4	37,07,085	276,648	4 4 3
Hyderabad (*a*) . .	34,55,648	257,884	4 11 3	35,31,253	263,526	4 5 3
Punjab	3,10,448	23,168	6 11 8	2,89,895	21,634	6 11 6
Rajputana	1,85,570	13,848	6 12 5	1,99,842	14,914	5 10 8
Total .	**8,84,96,027**	**6,604,106**	..	**8,93,59,124**	**6,668,591**	..
Average .	..	..	*3 14 10*	..	..	*3 13 6*

(*a*) Estimated.

TABLE 5.—*Origin of Indian Coal raised during the years 1928 and 1929.*

—	Average of last five years.	1928.	1929.
	Tons.	Tons.	Tons.
Gondwana coalfields	21,109,048	22,153,314	23,001,586
Tertiary coalfields	431,559	389,558	417,148
Total .	**21,540,607**	**22,542,872**	**23,418,734**

TABLE 6.—*Output of Gondwana coalfields for the years 1928 and 1929.*

—	1928.		1929.	
	Tons.	Per cent. of Indian Total.	Tons.	Per cent. of Indian Total.
Bengal, Bihar and Orissa—				
Bokaro	2,026,791	8·99	2,118,703	9·05
Daltonganj	929	0·01	1,522	0·01
Giridih	804,118	3·57	771,165	3·29
Hutar	205	0·00	357	0·00
Jainti	48,059	0·21	40,732	0·17
Jharia	10,665,479	47·31	10,785,745	46·05
Karanpura	390,493	1·73	467,127	1·99
Rajmahal Hills	636	0·00	565	0·00
Ramgarh	386	0·00	..	..
Rampur (Raigarh-Hingir)	31,623	0·14	36,774	0·16
Raniganj	6,460,490	28·66	6,828,053	29·16
Talcher	38,237	0·17	47,505	0·20
Central India—				
Sohagpur	117,423	0·52	92,508	0·39
Umaria	101,327	0·45	112,624	0·48
Central Provinces—				
Ballarpur	175,872	0·78	202,061	0·86
Pench Valley	556,481	2·47	680,270	2·90
Hyderabad—				
Sasti	35,615	0·16	47,455	0·23
Singareni	699,150	3·10	768,420	3·28
Total	**22,153,314**	*98·27*	**23,001,586**	*98·22*

TABLE 7.—*Output of Tertiary coalfields for the years 1928 and 1929.*

—	1928.		1929.	
	Tons.	Per cent. of Indian Total.	Tons.	Per cent. of Indian Total.
Assam—				
Khasi and Jaintia Hills	588	1·32	970	1·38
Makum	238,926		262,987	
Naga Hills	58,575		58,558	
Baluchistan—				
Khost	2,542	0·08	3,163	0·07
Sor Range, Mach, Kalat	15,389		13,059	
Punjab—				
Jhelum	24,674	0·21	20,506	0·18
Mianwali	18,161		19,064	
Shahpur	3,317		3,566	
Rajputana—				
Bikaner	27,386	0·12	35,275	0·15
Total	**389,558**	*1·73*	**417,148**	*1·78*

The export statistics for coal during 1929 show a large increase of over 100,000 tons, following an increase in the previous year of some 49,000 tons, the total exports of coal and coke rising from 626,343 tons to 726,610 tons, 2,281 tons of the latter being coke (see Table 8). The increase in exports is due chiefly to Hongkong, which absorbed some 196,000 tons. As before, the major portion of the exports went to Ceylon, which took nearly 15,000 tons more than during the previous year. Exports to the Straits Settlements (including Labuan), showed a slight increase. On the other hand the Philippine Islands and Guam took a considerably smaller quantity than in 1928. Other countries absorbed nearly 12,000 tons more.

TABLE 8.—*Exports to foreign ports of Indian Coal and Coke during the years 1928 and 1929.*

—	1928.			1929.		
	Quantity.	Value (£1 = Rs. 13·4).		Quantity.	Value (£1 = Rs. 13·4).	
	Tons	Rs.	£	Tons.	Rs.	£
To—						
Ceylon . .	351,496	42,65,166	318,296	366,332	43,76,107	326,575
Hongkong . . .	110,701	13,43,907	100,292	196,074	14,84,510	110,784
Philippine Islands and Guam	72,089	5,83,546	43,548	58,466	4,98,974	37,237
Straits Settlements (including Labuan).	71,040	7,77,565	58,027	74,231	8,34,054	62,243
Other countries . .	17,544	2,07,818	15,509	29,226	3,19,840	23,869
TOTAL .	622,870	71,78,002	535,672	724,329	75,13,494	560,708
Coke	3,473	69,595	5,193	2,281	43,838	3,272
Total of coal and coke .	626,343	*72,47,597*	*540,865*	726,610	*75,57,332*	*563,980*

These increased export figures are still below those of some earlier years (for example, 1,224,758 tons in 1920). As they are partly the result of the first four years' operations of the Indian Coal Grading Board, established for the purpose of certifying the quality of coal exported from the port of Calcutta, they are, however, on the whole, a favourable augury for the future prospects of this scheme for the rehabilitation of Indian coal in foreign markets. The following table shows the amounts of different grades of coal

exported during 1928 and 1929 under the above scheme (including sea-borne coal for railways in Southern India, for which no grade shipment certificates were issued by the Coal Grading Board), the difference between the total amounts so exported (2,529,013 tons in 1929) and the total exports of Indian coal to foreign ports given in Table 8 (726,610 tons in 1929) being the amount of coal exported to Indian ports.

TABLE 9.—*Exports of Coal under Grading Board Certificates during the years 1928 and 1929.*

—	1928.	1929.
	Tons.	Tons.
Selected grade	1,836,253	2,133,347
Grade I	422,628	390,802
Grade II	3,926	2,411
Mixed grades	43,580	1,854
Under reference	1,955	599
Total	2,308,342	2,529,013

Imports of coal and coke increased from 210,186 tons in 1928 to 218,560 tons in 1929; 14,031 tons of the latter consisted of coke (see Table 10). This increase is due to a rise of some 52,000 tons in the imports from South Africa, balanced partly by a decrease of some 4,000 tons from each of the United Kingdom and Australia, and of some 31,000 tons from Portuguese East Africa. The total imports are now less than half those of the pre-war quinquennium and Table 11, comparing pre-war imports and exports with the figures from 1926 to 1929, shews that the depression in the Indian coal industry, which continued till nearly the end of 1928, can no longer be looked upon as attributable to the competitive effect of foreign imported coal. The average surplus of exports over imports during the years 1926 to 1929 was, in fact, greater than the surplus during the pre-war quinquennium.

TABLE 10.—*Imports of Coal and Coke during the years 1928 and 1929.*

—	1928.			1929.		
	Quantity.	Value (£1 = Rs. 13·4).		Quantity.	Value (£1 = Rs. 13·4).	
	Tons.	Rs.	£	Tons.	Rs.	£
From—						
Australia	5,321	1,16,178	8,670	1,043	10,430	778
Portuguese East Africa	31,577	5,80,836	43,346	150	3,300	246
United Kingdom	34,419	8,12,021	60,599	30,337	6,31,723	47,144
Union of South Africa	113,431	22,14,144	165,235	165,965	30,89,100	230,530
Other countries	3,468	56,849	4,242	7,034	1,02,138	7,622
TOTAL	188,216	37,80,028	282,092	204,529	38,36,691	286,320
Coke	21,970	6,82,096	50,902	14,031	4,50,627	33,629
Total of coal and coke	**210,186**	***44,62,124***	***332,994***	**218,560**	***42,87,318***	***319,949***

TABLE 11.—*Excess of exports over imports of Coal.*

	Exports.	Imports.	Excess of exports over imports.
	Tons.	Tons.	Tons.
Average for 1909-1913	814,475	466,162	**348,313**
1926	617,563	193,908	**423,655**
1927	576,167	243,603	**332,564**
1928	626,343	210,186	**416,157**
1929	726,610	218,560	**508,050**

The average number of persons employed in the coalfields during the year showed a very slight decrease in spite of the substantial increase in production. The average output per person employed, therefore, again showed an advance on the previous years, the figure of 110·5 tons for 1925 rising to 113·1 tons for 1926, 122·3 tons for 1927, 125·5 tons for 1928 and 130·4 tons for 1929. The figure for the year under review is higher than any previously recorded, and is due, partly to an increased use of mechanical coal-cutters, and partly to concentration of work. During the past few years a large number of collieries have been shut down and the labour absorbed in the remainder; this concentration permits of a proportional reduction in the supervising staff, resulting in a larger tonnage per head. There was a decrease in the number of deaths by accident; these amounted to 212, which is an improvement on the annual average for the quinquennium 1919-1923, which was 274, and is close to the annual average for the quinquennium

1924-1928, which was 218. In addition, it relates to a production which is over 3 million tons in excess of the average for 1919-1923 and nearly $1\frac{1}{2}$ million tons in excess of the average for 1924-1928. The death rate was 1·2 per thousand persons employed in 1929, against 1·3 for 1928; the average figure for the period 1919-1923 was 1·36, and for the period 1924-1928 was 1·16.

TABLE 12.—*Average number of persons employed daily in the Indian coalfields during the years 1928 and 1929.*

	Number of persons employed daily.		Output per person employed in tons.	Number of deaths by accident.	Death rate per 1,000 persons employed.
	1928.	1929.			
Assam	4,216	4,145	77·8	11	2·7
Baluchistan	254	278	58·3	..	..
Bengal	43,855	44,303	134·6	62	1·4
Bihar and Orissa	108,546	109,082	138·7	106	1·0
Central India	3,144	2,617	78·4	2	0·8
Central Provinces	6,923	7,656	115·2	13	1·7
Hyderabad	11,816	10,651	76·5	16	1·5
Punjab	766	743	58·1	2	2·7
Rajputana	167	132	267·2	..	..
TOTAL	**179,687**	**179,607**	..	**212**	..
Average	..	..	*130·4*	..	*1·2*

Cobalt (*see* Nickel).

Copper.

The progress of work at the Mosaboni Mine of the Indian Copper Corporation, Ltd., in the Singhbhum district, and on the milling and smelting plant at Maubhandar, near Ghatsila, Bengal Nagpur Railway, has been noticed in previous reviews. Operations commenced on a revenue basis on January 1st 1929, and the year under review, marks, therefore, the first full year's production. 75,830 short tons of ore were hoisted from the mine and 75,174 short tons treated in the mill and smelter, with the production of 1,635 long tons of refined copper ingots and slabs. The copper was sold entirely in India at an average price of Rs. 1,200 per long ton.

The surface and underground ore reserves now total 798,154 short tons of 3·33 per cent. ore, representing a content of 26,546 short tons of copper.

The amount of ore produced by the company in 1929 was 76,831 tons valued at Rs. 14,58,746 (£108,862).

There was a slight increase in the production of copper matte at the Namtu smelting plant of the Burma Corporation Limited. The production during 1928 was 10,978 tons valued at Rs. 46,26,403 (£345,254) averaging 39·6 per cent. of copper, and during 1929 11,303 tons valued at Rs. 50,20,544 (£374,667) averaging 39·84 per cent. of copper 29·70 per cent. of lead and 63·27 ozs. of silver to the ton. The matte is exported to Hamburg for further treatment.

A small output of 5 tons of copper ore was reported from the Mysore state in 1929, but the value was not reported.

Diamonds.

The production of diamonds in Central India rose from 823·8 carats valued at Rs. 65,491 (£4,887) in 1928 to 1,627·5 carats valued at Rs. 52,045 (£3,884). Of this latter production 1,475·7 carats were produced in Panna state and the remainder in Charkhari, Ajaigarh and Bijawar.

Gold.

The gradual secular decline in the total Indian gold production continued, the decrease being from 376,062·8 ozs. valued at £1,588,252 in 1928 to 363,869·4 ozs. valued at £1,542,109 in 1929, almost the whole of this decline being due to the Kolar goldfield.

Of the five mines producing gold on the Kolar goldfield, the Champion Reef and the Ooregum mines reached vertical depths of 6,850 feet and 6,772 feet, respectively, below field datum, on the 31st of December, 1928. A gratifying feature of the developments in depth is the continuity of the reef and the opening up of large bodies of payable ore. The dip of the reef, however, is becoming much steeper and is almost vertical in the lower levels. The ore is not refractory and yields its gold to a simple combination of amalgamation and cyaniding; 'all-sliming' is gradually becoming general and battery plate amalgamation is being gradually eliminated. The rock temperatures at the above great depths are 122·4° Fah. and 119·4° Fah., respectively. Owing to the depth of the mines and the high rock temperatures, the problem of ventilation has been an extremely difficult one. It has been solved to some extent by sinking deep vertical shafts and by an extensive

use of large electrically-driven fans to help the main air currents. A large volume of air is constantly kept in circulation by these fans installed in convenient places in the main airways. The brick and concrete lined shafts and winzes, which are coming more and more into vogue in deep-level mining in this field, considerably assist the free movement and increase the circulation of the air by reduction of friction. The shafts themselves are cleaner and less liable to damage by rock-bursts. The latter, even with the improved and more rigid forms of support adopted in place of the usual timbering and waste-rock filling, are still a source of anxiety and at times cause considerable damage to underground workings.

The working population on the Kolar goldfield at the end of 1929 was 18,451, of which 3,610 persons were employed on the Champion Reef mine and 4,209 on the Ooregum mine.

TABLE 13.—*Quantity and value of Gold produced in India during the years 1928 and 1929.*

—	1928.			1929.			Labour
	Quantity.	Value (£1 = Rs. 13·4).		Quantity.	Value (£1 = Rs. 13·4)		
	oz.	Rs.	£	oz.	Rs.	£	
Bihar and Orissa—Singhbhum .	7·0	352	26	30·0	1,500	112	12
Burma—							
Katha . .	16·6	1,066	79	23·5	1,420	106	5
Upper Chhindwin.	54·7	4,741	354	12·6	1,102	82	(*a*)
Kashmir . .	60·0	2,520	188	56·8	2,700	201	62
Mysore . .	375,386·0	2,12,72,297	1,587,485	363,741 4	2,06,57,288	1,541,585	18,454
Punjab . .	84·0	1,369	102	1·9	108	8	7
United Provinces	4 5	240	18	8·7	200	15	11
TOTAL .	376,068·8	*2,12,82,585*	*1,588,252*	363,869·4	*2,06,64,268*	*1,542,109*	*18,551*

(*a*) Not available.

Ilmenite.

There was a decrease in the production of ilmenite in the Travancore state, from 25,307 tons valued at £41,557 in 1928 to 23,670 tons valued at £28,602 in 1929. This mineral is collected with the monazite sands and, up to a few years ago, was looked upon as a bye-product of the monazite industry. Now-a-days, the increasing demand for the titania in the ilmenite is causing a resuscitation of the monazite industry, which had been adversely affected by the increased use of electricity for lighting purposes.

Iron.

The production of iron-ore in India is still steadily on the increase; India is now, in fact, the second largest producer in the British Empire, and yields place only to the United Kingdom. Her output is of course still dwarfed by the production in the United States (over 60 million tons) and France (over 40 million tons); her reserves of ore are, however, not much less than three-quarters of the estimated total in the United States, and there is every hope that India will in the early future take a much more important place among the world's producers of iron-ore. In 1929 there was an increase in the Indian output over the previous year of 18·1 per cent. amounting to 372,563 tons. The figures shown against the Keonjhar and Mayurbhanj States in Table 14 represent the production by the United Steel Corporation of Asia, Ltd., and the Tata Iron & Steel Co., Ltd., respectively. Of the total production of 1,390,245 tons shown against Singhbhum, 461,529 tons were produced by the Tata Iron & Steel Co., Ltd., from their Noamundi mine, 427,477 tons by the Bengal Iron Co., Ltd., from their Pansira, Ajita and Maclellan mines, and 466,602 tons by the Indian Iron & Steel Co., Ltd., from their mines at Gua; the remaining 34,637 tons were produced by another firm. The output of iron-ore in Burma is by the Burma Corporation Limited and is used as a flux in lead smelting.

TABLE 14.—*Quantity and value of Iron-ore produced in India during the years 1928 and 1929.*

—	1928.			1929.		
	Quantity.	Value (£1 = Rs. 13·4).		Quantity.	Value (£1 = Rs. 13·4)	
	Tons.	Rs.	£	Tons.	Rs.	£
Bihar and Orissa—						
Keonjhar	141,361	(a) 4,24,083	31,648	187,203	7,48,812	55,882
Mayurbhanj	683,493	20,50,479	153,021	759,875	22,79,625	170,121
Sambalpur	21	265	20	21	14[illegible]	11
Singhbhum	1,131,746	26,98,120	201,352	1,390,245	31,62,727	236,024
Burma—						
Mandalay	559	2,236	167	..	..	..
Northern Shan States	74,254	2,97,016	22,165	46,140	1,84,560	13,773
Central Provinces	934	3,972	2[illegible]6	715	2,145	160
Mysore	28,624	58,841	4,391	44,356	1,13,222	8,449
TOTAL	**2,055,999**	*55,36,012*	*413,060*	**2,428,565**	*64,91,236*	*484,429*

In contrast to the preceding year there was a rise in the output of iron and steel by the Tata Iron & Steel Co. at Jamshedpur. The production of pig-iron and steel (including steel rails) rose respectively from 510,884 tons and 289,865 tons in 1928 to 722,950 tons and 410,923 tons in 1929, and of ferromanganese from 3,233 tons in 1928 to 3,630 tons in 1929. The production of pig-iron by the Bengal Iron Co. rose from 128,112 tons in 1928 to 196,080 tons in 1929; their output of products made from their pig-iron in 1929 amounted to 11,153 tons of sleepers and chairs and 32,445 tons of pipes and other castings, against 20,282 tons and 27,180 tons, respectively, in 1928. The Indian Iron & Steel Co. increased their production of pig-iron from 397,784 tons in 1928 to 451,059 tons in 1929. The output of pig-iron by the Mysore Iron Works rose from 15,104 tons in 1928 to 21,452 tons in 1929. The total production of pig-iron in India in 1929 was 1,391,541 tons against 1,051,884 tons in 1928.

The total number of indigenous furnaces that were at work in the Central Provinces during the year 1929 for the purpose of smelting iron-ore was 174 against 196 in the previous year; 95 furnaces were operating in the Bilaspur district, 53 in Mandla, 11 in Drug, 12 in Raipur, 3 in Saugor and none in Jubbulpore.

With the increase in the production of pig-iron in India recorded above, the quantity exported rose from 428,625 tons in 1928 to 548,881 tons in 1929. Table 15 shows that Japan is still the principal consumer of Indian pig-iron, over 70 per cent. of the total exports having gone to that country in 1929. There was a fall in the export value per ton of pig-iron from Rs. 47·0 (£3·51) in 1928 to Rs. 45·7 (£3·41).

The Steel Industry (Protection) Act, 1924, Act No. XIV of 1924, authorised, to companies employing Indians, bounties upon rails and fishplates wholly manufactured in British India from material wholly or mainly produced from Indian iron-ore and complying with specifications approved by the Railway Board, and upon iron or steel railway wagons, a substantial portion of the component parts of which had been manufactured in British India. This Act was repealed by the Act No. III of 1927 and the payment of bounties consequently ceased on the 31st March, 1927; the industry is, however, protected to a certain extent by varying tariffs on different classes of imported steel.

TABLE 15.—*Exports of Pig-iron from India during the years 1928 and 1929.*

—	1928.			1929.		
	Quantity.	Value (£1 = Rs. 13·4).		Quantity.	Value (£1 = Rs. 13·4).	
	Tons.	Rs.	£	Tons.	Rs	£
To—						
Germany	8,542	3,84,375	28,685	13,243	6,01,460	44,885
Japan	321,010	1,52,72,858	1,139,765	385,158	1 75 44 598	1,309,298
United Kingdom	8,920	4,04,166	30,162	43 905	20,64,013	154 031
United States of America	57,897	26,02,478	194,214	68,017	30,62,606	228 553
Other countries	32,256	14,86,917	110,964	38,558	18,13,478	135,334
TOTAL	428,685	*2,01,50,789*	*1,503,790*	548,831	*2,50 86,155*	*1,872,101*

Jadeite.

There was a further increase in the output of jadeite, which rose from 2,845 cwts. valued at Rs. 2,85,984 (£21,342) in 1928 to 3,450·9 cwts., valued at Rs. 2,77,356 (£20,698) in 1929. The output figures are liable to be incomplete, and a more correct idea of the extent of the Burmese jadeite industry, especially of values, is sometimes obtainable from the export figures. Exports by sea fell from 2,698 cwts. valued at Rs. 5,82,4 71 (£43,468) in the year 1928-29 to 2,137 cwts. valued at Rs. 4,86,156 (£36,280) in the year 1929 30. These figures exclude exports by land across the frontier to foreign countries, as the registration of the Land Frontier Trade of Burma has been discontinued.

Lead.

The production of lead-ore at the Bawdwin mines of Burma increased slightly from 442,503 tons in 1928 to 463,972 tons in 1929, and the total amount of metal extracted increased from 78.384 tons of lead (including 1,241 tons of antimonial lead) valued at Rs. 2,22,05,126 (£1,657,099) to 80,233 tons of lead (including 1,200 tons of antimonial lead) valued at Rs. 2,50,00,613 (£1,865.717) in 1929. The quantity of silver extracted from the Bawdwin ores fell from 7,404,728 ozs. valued at Rs. 1,19,26,055 (£890,004) in 1928 to 7,280,517 ozs. valued at Rs. 1,07,31,482 (£800,857) in 1929. The value of lead per ton rose from Rs. 283·3 (£21·1) in 1928 to Rs. 311·6 (£23·2) in 1929, but the value of silver fell from Rs. 1-9-10 (28·85*d.*) per oz. in 1928 to Rs. 1-7-7 (26·40*d.*) per oz. in the year under review. The ore reserves in the Bawdwin mine, as calculated at the end of June, 1929, totalled 4,140,969 tons against 4,092,751 tons at the end of June, 1928, with an average composition of 25·49

TABLE 16.—*Production of Lead-ore, Lead and Silver during the years 1928 and 1929.*

	1928.					1929.				
	Quantity.	Value (£1 = Rs. 13·4).				Quantity.	Value (£1 = Rs. 13·4).			
	Lead-ore.	Lead-ore and lead.		Silver.		Lead-ore.	Lead-ore and lead.		Silver.	
	Tons.	Rs.	£	Rs.	£	Tons.	Rs.	£	Rs.	£
Burma—										
Northern Shan States	443,508	(a) 2,22,05,126	1,657,099	(b) 1,19,26,055	890,004	463.972	(c) 2,50,00,613	1,865,717	(d) 1,07,31,482	800,857
Southern Shan States	1,151	1,15,170	8,595	..	..	719	66,590	4,969	..	..
Rajputana—										
Jaipur State	..	..	..	..	..	5	1,500	112	..	..
Total	[illegible]	*2,23,20,296*	*1,665,694*	*1,19,26,055*	*890,004*	[illegible]	*2,50,68,793*	*1,870,798*	*1,07,31,482*	*800,857*

(a) Value of 77,143 tons of lead (Rs. 2,18,88,115) and 1,241 tons of antimonial lead (Rs. 3,17,011) extracted.
(b) Value of 7,404,728 ozs. of silver extracted.
(c) Value of 79,033 tons of lead (Rs. 2,46,63,512) and 1,200 tons of antimonial lead (Rs. 3,37,101) extracted.
(d) Value of 7,280,517 ozs. of silver extracted.

per cent. of lead, 16·0 per cent. of zinc and 21·5 ozs. of silver per ton of lead. Included in this reserve are 300,000 tons of copper-ore containing, approximately, 13 per cent. of lead, 8 per cent. of zinc, 7 per cent. of copper and 18 ozs. of silver per ton.

Magnesite.

There was a slight decrease in the magnesite output from the Salem district of Madras, but the figure for 1929, 22,134 tons valued at Rs. 1,08,722 (£8,114), is still well below those for the years 1925 and 1926, which were in the neighbourhood of 30,000 tons. There was a decrease in the output from Mysore. The total decrease in output in India amounted to 909 tons, accompanied by a decrease in value of Rs. 31,215 (£2,329).

TABLE 17.—*Quantity and value of Magnesite produced in India during the years 1928 and 1929.*

—	1928.			1929.		
	Quantity.	Value (£1=Rs. 13·4).		Quantity.	Value (£1=Rs. 13·4).	
	Tons.	Rs	£	Tons.	Rs.	£
Madras—						
Salem . .	22,542	1,41,742	10,578	22,134	1,08,722	8,114
Mysore State .	1,864	18,640	1,391	1,363	20,445	1,526
Total .	*24,406*	*1,60,382*	*11,969*	*23,497*	*1,29,167*	*9,640*

Manganese.

Before the year 1926, the record production of manganese-ore in India took place in the year 1907, when 902,291 tons were raised. In 1926, the output rose to 1,014,928 tons, valued at £2,463,491 f. o. b. Indian ports; the rise in output was, however, accompanied by a decrease in value. In 1927 the production rose to the highest

figure yet recorded, 1,129,353 tons, accompanied by a rise in value to the peak figure of £2,703,068 f. o. b. Indian ports. During the year 1928, the upward tendency was not maintained, the output falling to 978,449 tons, valued at £2,198,895 f. o. b. Indian ports. In 1929, the output rose slightly to 994.279 tons, but the value fell heavily to £1,571,030. In 1924, first-grade ore, c. i. f. United Kingdom ports, fetched an average price of 22·9*d*. per unit. In 1925, this price fell to 21·5*d*., in 1926 to 18·4*d*., in 1927 to 18·1*d*., in 1928 to 17·0*d*., with a heavy fall in 1929 to an average price of 14·0*d*. per unit. This is only 1*d*. above the *post-war lower governing price of manganese*,* with an index figure of cost of supplies and services of 1·45. This continued fall in the price of manganese-ore from 1924 to 1929 is to be correlated with the fact that from 1924 to 1927 the rate of increase of the world's production of manganese-ore was much greater than the rate of increase in the world's production of pig-iron and steel. The fact that the world's production of pig-iron and steel in 1929 exceeded the production of 1928, whilst the production of manganese-ore was probably less, has not arrested the fall, in view of the fact that the available supplies of manganese-ore are now much in excess of requirements. Russia, by non-economic methods of exploitation and finance, is able to place large quantities of ore on the market at a price below the critical figure of 13·0 pence referred to above. The large deposits of high-grade manganese-ore discovered near Postmasburg in South Africa are also being developed, and on the completion of the railway line now under construction, it may be anticipated that South Africa will secure a substantial portion of the world's market. It is not surprising, therefore, that in spite of the apparent prosperity of the Indian manganese industry in 1929, as judged from figures of production and export, yet at the time of writing (August 1930) the industry as a whole is in a state of relative depression and many operators have ceased work.

The present chief sources of production of manganese-ore are now India, Russia, the Gold Coast, and Brazil, whilst substantial supplies of ore are forthcoming from Egypt and Czechoslovakia.

There is a steady consumption of manganese-ore at the works of the three principal Indian iron and steel companies, not only for use in the steel furnaces of the Tata Iron and Steel Company,

* See *Rec. Geol. Surv. Ind.*, Vol. LXIV, p. 192, (1930).

and for the manufacture of ferro-manganese, but also for addition to the blast-furnace charge in the manufacture of pig-iron. The consumption of manganese-ore by the Indian iron and steel industry in the year under review amounted to 47,435 tons, against 69,872 tons in 1928.

TABLE 18.—*Quantity and value of Manganese-ore produced in India during the years 1928 and 1929.*

—	1928.		1929.	
	Quantity.	Value, f.o.b. at Indian ports.	Quantity.	Value, f.o.b. at Indian ports.
	Tons.	£	Tons.	£
Bihar and Orissa—				
Gangpur State	6,379	15,337	..	..
Keonjhar State	72,411	131,547	53,433	62,338
Singhbhum	23,199	55,773	22,698	38,965
Bombay—				
Belgaum	1,603	3,854	8,666	14,877
Chhota Udepur	7,267	17,214	9,415	15,888
North Kanara	3,601	8,656	6,245	10,721
Panch Mahals	63,040	151,559	56,326	96,693
Central India—				
Jhabua	3,835	7,447	..	..
Central Provinces—				
Balaghat	248,497	632,632	263,105	482,359
Bhandara	89,059	226,730	156,525	286,962
Chhindwara	37,069	94,371	29,814	54,659
Nagpur	216,509	551,195	172,559	316,358
Madras—				
Bellary	5,257	7,579	10,535	9,131
Sandur State	139,801	201,546	140,604	121,857
Vizagapatam	29,004	45,580	24,533	23,715
Mysore—				
Chitaldrug	1,907	2,869	667	611
Shimoga	27,994	42,108	38,436	35,233
Tumkur	1,927	2,898	718	663
Total	**978,449**	*2,198,895*	**994,279**	*1,571,030*

Table 20 shows the distribution of manganese-ore exported from British Indian ports (excluding the Portuguese port of Mormugao) during 1928 and 1929, from which it will be seen that the United Kingdom, with an increase in imports of 105,310 tons, has resumed her position as chief importer of Indian manganese-ore, a position she had lost in 1928, when she ranked after France and Belgium. France increased her imports by some 24,000 tons, whilst Belgium decreased hers slightly. Germany, who increased her imports in 1927 and 1928, showed a substantial decrease of over 8,000 tons in 1929. The Netherlands showed a large increase amounting to about 29,000 tons. Italy showed a decrease of some 5,000 tons. The supply to the United States again dropped, from 76,000 to 51,250 tons. Other countries increased their takings by over 4,000 tons.

TABLE 19.—*Exports of Manganese-ore during 1928 and 1929 according to ports of shipment.*

Port.	1928.	1929.
	Tons.	Tons.
Bombay	270,961	325,268
Calcutta	378,604	440,302
Madras	9,002	13,930
Mormugao (Portuguese India)	175,577	184,989
Total	834,144	964,489

TABLE 20.—*Exports of Manganese-ore from British Indian ports during the years 1928 and 1929.*

—	1928.			1929.		
	Quantity.	Value (£1 = Rs. 13·4).		Quantity.	Value (£1 = Rs. 13·4).	
	Tons.	Rs.	£	Tons.	Rs.	£
To—						
United Kingdom	159,227	44,77,671	334,154	264,537	77,87,790	581,178
Germany	20,945	5,49,002	40,970	12,630	3,25,700	24,306
Netherlands	7,501	2,45,525	18,323	36,350	10,26,112	76,576
Belgium	183,897	51,61,358	385,176	181,174	48,62,257	362,855
France	195,576	57,34,567	427,953	219,055	59,71,778	445,655
Italy	9,475	3,17,387	23,686	4,246	1,49,920	11,188
United States of America	76,000	22,44,750	167,519	51,250	15,38,500	114,813
Other countries	5,946	2,24,998	16,790	10,308	2,75,804	20,582
Total	658,567	*1,89,55,253*	*1,414,571*	779,550	*2,19,37,861*	*1,637,158*

Mica.

There was a further increase in the declared production of mica from 45,112 cwts. valued at Rs. 24,10,499 (£179,887) in 1928 to 53,231 cwts. valued at Rs. 26,59,759 (£198,489) in 1929. This is the highest production yet recorded, with the exception of that of 1918 (54,710 cwts.). As has been frequently pointed out, the output figures are incomplete, and a more accurate idea of the size of the industry is to be obtained from the export figures. It will be seen from Table 22 that in the years 1928 and 1929 the quantity exported was more than double the reported production. In both the years 1926 and 1927 also the export figure was approximately double the reported production figure. The United States of America and the United Kingdom, which are the principal importers of Indian mica, absorbed 25·1 per cent. and 44·6 per cent. respectively, of the total quantity exported during 1928 and 34·6 per cent. and 41·7 per cent., respectively, during 1929. Germany took 16·0 per cent. and 8·8 per cent., respectively, of the total quantities exported during the years 1928 and 1929. The average value of the exported mica fell from Rs. 98·0 (£7·3) per cwt. in 1928 to Rs. 90·5 (£6·7) per cwt. in 1929. The exports for 1929 (116,075 cwts.) are the highest yet recorded, the previous highest being 99,699 cwts. in 1925. The value (£784,092) was, however, exceeded by the values of the exports of 1920 (76,517 cwts. valued at £1,065,438), 1925 (99,699 cwts. valued at £799,483) and 1926 (89,947 cwts. valued at £820,901).

The difference between exports and production is generally attributed to theft from the mines. If this be the only explanation we must assume that during the past thre years there has been as much mica stolen as won by honest means. Early in 1928 a bill was introduced into the Legislative Council of Bihar and Orissa, the purpose of which was an attempt to reduce the losses on this account by licensing miners and dealers; the bill was, however, rejected. In March, 1930, however, a similar bill to regulate the possession and transport of, and trading in mica was passed.

TABLE 21.—*Quantity and value of Mica produced in India during the years 1928 and 1929.*

	1928.			1929.		
	Quantity.	Value (£1 = Rs. 13·4).		Quantity.	Value (£1 = Rs. 13·4).	
	Cwts.	Rs.	£	Cwts.	Rs.	£
Bihar and Orissa—						
Gaya	2,452	1,00,704	7,515	8,887	2,80,552	20,937
Hazaribagh	32,419	17,61,507	131,456	33,839	17,82,736	133,040
Monghyr	267	14,084	1,051	324	14,146	1,056
Sambalpur	5	131	10	..	..	..
Santal Parganas	..	..	..	10	350	26
Gwalior	140	6,877	513	25	1,776	132
Madras—						
Nellore	8,838	4,77,328	35,621	10,085	5,45,854	40,735
Nilgiris	109	10,068	751	109	10,176	760
Rajputana—						
Ajmer-Merwara	539	29,733	2,219	311	17,479	1,304
Jaipur State	..	..	..	37	3,000	224
Shahpura State	343	10,067	751	104	3,690	275
Total	**45,112**	*24,10,499*	*179,887*	**53,231**	*26,59,759*	*198,489*

80 cwts. of uncut mica were produced in Patiala State in the Punjab during 1929.

TABLE 22.—*Quantity and value of Mica exported from India during the years 1928 and 1929.*

	1928.			1929.		
	Quantity.	Value (£1 = Rs. 13·4).		Quantity.	Value (£1 = Rs. 13·4).	
	Cwts.	Rs.	£	Cwts.	Rs.	£
To—						
United Kingdom	42,556	45,91,826	342,674	40,132	42,89,252	320,003
Germany	15,286	11,11,349	82,936	10,190	6,19,395	46,224
France	3,983	4,29,509	32,053	7,506	4,66,624	34,823
United States of America	23,968	22,39,370	167,117	48,348	43,76,606	326,612
Other countries	9,686	9,82,892	73,350	9,899	7,54,957	56,340
Total	**95,479**	*93,54,946*	*698,130*	**116,075**	*1,05,06,834*	*784,092*

Monazite.

The monazite industry of Travancore, which was moribund in the year 1925, when the reported production was 1 cwt. only, showed signs of revival in 1926, the output amounting to 64·2 tons valued at £947. The production rose to 280 tons valued at £3,810 in 1927, fell to 103·4 tons valued at £1,242 in 1928, and rose again to 180 tons valued at £1,800 in 1929. The decline of the industry is of course due to the supplanting of incandescent mantles for gas lighting by electricity. It is hoped that ilmenite, collected with the monazite and hitherto regarded as a bye-product, may be the means of reviving the industry; titania forms a valuable white paint superior to white lead in being non-poisonous and in possessing twice the covering power.

Nickel.

As a bye-product in the smelting operations of the Burma Corporation, Limited, at Namtu, in the Northern Shan States, there is now a regular production of nickel-speiss, which in 1927 amounted to 1,032 tons, and in 1928 to 2,933 tons, the latter production being valued at Rs. 5,34,961 (£39,922). In 1929 there was a further rise to 3,065 tons valued at Rs. 6,38,780 (£47,670) containing 27·08 per cent. of nickel, 13·16 per cent. of copper and 30·03 oz. of silver to the ton. This speiss is shipped to Hamburg for further treatment. It contains from 3 to 4 per cent. of cobalt.

Petroleum.

The world's production of petroleum in 1926 amounted to a little over 151½ million metric tons, of which India contributed 0·79 per cent. In 1927, this figure jumped to some 171 million metric tons, of which the Indian proportion, on a practically stationary production, fell to 0·72 per cent. In 1928, there was another substantial rise in the world's production which reached the figure of over 181 million metric tons. In 1929, there was another jump to nearly 203 million metric tons. For this rise the United States and Venezuela were mostly responsible, but Russia, the Dutch East Indies, Roumania, Peru, Trinidad, Canada, Columbia, Ecuador, Argentina, Persia and smaller producers all contributed to the increase. There was a decline in the case of Mexico and India. The United States contributed 67 per cent. of the world's supply in 1929 and Venezuela 9·7 per cent. of the total world's production. In 1928, India

contributed 0·70 per cent., which fell to 0·61 per cent. in 1929; her position on the list of petroleum-producing countries fell from 11th in 1928 to 12th in the year under review, her place being taken by Trinidad.

Although petroleum statistics prove that it is becoming more and more difficult to maintain the output of India (including Burma) at the high levels it reached in 1919 and 1921, when peak productions of well over 305½ million gallons were reached, the production thereafter falling to 281,113,909 gallons in 1927, yet the production during 1928 reached the figure of 305,943,711 gallons, and in 1929 the figure of 306,148,093 gallons, which is the highest ever recorded. This slight increase in output in 1929 was accompanied by a substantial increase in value amounting to Rs. 65,15,623 (£486,241). The increase in output recorded in 1928 and 1929, notable as it is, can only be regarded as an arrest in the decline which has set in and which, with possible interruptions, is likely to continue slowly and steadily during the present generation, unless a new field of importance is discovered. The chances of the latter recede year after year as exhaustive geological research continues to prove fruitless. A conservative policy rather than one of intensive development is indicated, especially in view of the national importance of this mineral asset.

The Yenangyaung field of Upper Burma, the most highly developed field in the Indian Empire, again shows a decline in output. In 1924, it succeeded in showing an increase of nearly 6½ million gallons, but this temporary arrest in the decline was more than neutralised by a drop in 1925 of over 21½ million gallons. In 1926, the drop amounted to 14½ million gallons, in 1927 to 8⅓ million gallons, in 1928 to 1⅓ million gallons, and in 1929 to one million gallons. It is interesting to note that the production in Yenangyaung still includes oil derived from the old Burmese hand-dug wells.

In the Yenangyaung field it is now seldom that a new well strikes a yield of over 50 barrels per initial 24 hours, nearly all the exceptions occurring in the Khodaung tract and in the previously untapped eastern extension of the 2,500—2,800 ft. sands. The higher production from the Burmah Oil Company's wells in Khodaung is due in part to the geological position of the block and to the relatively youthful stage of its producing life, but in the main to the proper scientific system of development it has been

possible to adopt there, as compared with the intensive competitive drilling in the reserved areas. The number of producing wells in the Yenangyaung field in 1928 amounted to nearly 2,450, including about 150 hand-dug wells, and in 1929 to nearly 2,750 including about 185 hand-dug wells. As in the previous year the exploitation of the shallow sands, which were originally drilled through without protection in the competitive rush for deeper sands, has been a prominent feature of development, and the production obtained from this source amounted at the end of the year to approximately 16 per cent. of the total production of the field.

The relative merits of repressuring and suction are now exercising the minds of operators in Yenangyaung. It seems probable that both processes, employed at the proper time, will be found useful in increasing the yield from the various sands to which they are applied. To make full use of gas pressure in the oil sands, it would appear advantageous to use the repressuring process as long as possible and to postpone the use of vacuum. The adverse effects of the latter are not only the removal of the driving force in the form of gas, but an abstraction of the lighter components of the crude oil causing earlier paraffination of the sands. On the other hand, it is difficult to decide to what extent the result of repressuring is an actual increase in the total crude oil extracted from the sand, or merely accelerated production. During the year there was a great increase in repressuring activities in areas operated by the Burmah Oil Company, including the extension of this method of stimulating recovery to intermediate and lower sands. Proposals were also considered for the co-operative repressuring of the Beme Reserve.

Of the several companies operating in this small field, the Burmah Oil Company produces about four-fifths of the total output. Very little contribution to our knowledge of deeper horizons in the field has been made during the year and the test well in Block 4S remained the deepest well in Burma, but owing to its mechanical condition it has not been possible to test the productivity of the sands encountered in it. A well in Block 6S reached a depth of 4,105 ft. without proving the existence of commercial accumulations of oil. Large volumes of gas have, however, been encountered in this well.

The theoretical and practical expectations based on the observed asymmetry of the Yenangyaung structure have been realised and

a number of wells completed during the year are yielding production on a commercial scale from horizons correlative with the 2,500—2,800 ft. zones of the field, in an area situated outside and to the east of the productive limits of the shallow sands.

During the year there were 15 outbreaks of fire. Out of 110 accidents reported during 1929, only 7 were fatal. The price of hand-dug oil at the river bank during the year in question averaged about Rs. 12-10-0 per 100 *viss* during the first quarter of the year.

The place of Yenangyaung is being steadily taken by the Singu field, which, in a few years, will undoubtedly usurp the premier position so far held by the older field. Singu, the greater part of which is in the hands of the Burmah Oil Company, is used to make good the deficiencies of Yenangyaung in order to maintain supplies to the refinery. In 1929, the output of Singu fell by some 22 million gallons. This decrease in production is due not to any actual decline in the potential productivity of the proved horizons, but to the policy of the Burmah Oil Company in taking from this field only sufficient oil to stabilise their refinery throughput. The restriction of production from this field has afforded the opportunity for experimental work on the control of pressure and it may be confidently anticipated that the results achieved will have a far reaching and beneficial effect on the ultimate recovery from the field. In addition to the wells completed and put to production, a large number were drilled to horizons situated just above productive sands and cemented there. These wells can be drilled into the productive sands in a very short time and the total field production substantially increased. Many wells are producing from the 3,000 foot sand.

Little contribution has been made to our knowledge of deeper horizons. A well in Block 57N was drilled to a depth of 4,910 ft. without obtaining production on a commercial scale below the 3,000 ft. zone. Considerable extension in the use of electric power, both for drilling and production, was made during the year, and has rendered possible large economies in the use of gas for fuel.

Drilling was first started on the Yenangyat field in 1891 by the Burmah Oil Company. The expansion was slow up to 1894, but rose rapidly to a yield of over 6 million gallons in 1898, and in 1903 the highest quantity recorded from this field was produced, namely, 22,665,518 gallons. Subsequent to that year, a decline set in,

gradual at first, but severe after 1906. Between 1909 and 1918, production averaged a little over 5 million gallons. From 1918, onwards the decline was gradual but persistent until 1925, when it had sunk to a little more than $1\frac{1}{2}$ million gallons. Since 1925, there has been a gradual recovery. In 1927, the output was 1,844,946 gallons. In 1928, the yield rose to 3,072,222 gallons, a stride due to increased drilling on the part of the Burmah Oil Company, and also to expansion by the Indo-Burma Petroleum Company in the Lanywa area in the south ; in 1929, the yield jumped to 17,606,935 gallons, due to increased production from Lanywa. In the Yenangyat field proper, 11 wells were completed during the year with an average production of nearly 20 barrels. One well in Block 9 is reported to have yielded an initial production of 200 barrels per day. A number of deep tests are in progress but none had proved accumulations of oil of commercial value at the end of the year.

It has long been recognised that the Lanywa oilfield is structurally more closely related to the Singu than the Yenangyat structure, and in September, 1929 the Lanywa area was notified as part of the Chauk oilfield. The embankment for the protection of the Lanywa-Sitpin sand bank was completed during the early part of the year and by the end of the year 12 producing wells had been drilled in this field, the total production for the year amounting to approximately 15,000,000 gallons, which is still included in the production of the Yenangyat field. The drilling of 4 more wells was in progress at the end of the year. As remarked before the striking of remunerative supplies of oil at Lanywa makes it almost certain that the river Irrawaddy covers oil deposits of commercial size. The question of reaching the sub-fluviatile deposit, by tunnelling beneath the river with chambers large enough to accommodate drilling derricks, is now under consideration.

Of the other Burma fields, Minbu showed a small decrease amounting to some 300,000 gallons. Some 220 wells were producing. In the Minbu field the limit of economic spacing was reached in the Shwelinban shallow well area. Of the deep test wells one has been abandoned, whilst that in Block 13S, encountered gas and oil below 2,300 ft. The initial production of oil was 125 barrels per diem with gas sufficient to supply the fuel requirements of the operations in the Palanyon portion of the field. The crude oil produced by this well is of higher grade than is produced

by the other known sands in the Minbu field and is, therefore, a valuable addition to the resources of this area. The heavy oil from Minbu is less profitable to refine than that produced from other fields.

There was a further noticeable improvement in the case of the Upper Chindwin, which again showed an increase, amounting to over 487,000 gallons. The Thayetmyo fields, which had shown a large decline in 1928, amounting to over 272,000 gallons, showed in 1929 a small increase of some 19,000 gallons. Of the Thayetmyo fields, Yenanma has been drilled to the limit of economic spacing and in 1929 showed a decline of approximately 10 per cent. of its 1928 production. The production of Padaukpin on the other hand showed a slight increase, due mainly to two shallow wells completed during the first half of the year. Tests are being carried out at Minhla. The output from Kyaukpyu remained at its usual low level, and that of Akyab fell by over 3,000 gallons to 1,980 gallons. In Assam, the Digboi field gave a somewhat disappointing increase of about 3 million gallons. An eastern extension well was started at Hansapung and a deep test of the Digboi field also has been begun. Operations at Burragolai have been suspended temporarily. In the Surma valley the output from the Badarpur field decreased by nearly 700,000 gallons, due to natural decline and failure to prove new sands or extensions. The number of wells drilled totals 60, but results have been disappointing. Drilling difficulties are unusually great while the decline in yield is abnormally rapid. A new well to test deep horizons was begun, but had not reached unexplored horizons before the end of the year. In the prospecting area of Masimpur production fell heavily by some 20,000 gallons to a little over 5,000 gallons. Water trouble has been experienced in the 4 wells drilled, and progress in the fourth well is prevented by caving, attempts to control which have not yet been successful. At Patharia no oil was produced during the year. The area is being tested by a second well which has not yet reached new horizons.

In the Punjab, the output from the Khaur field shewed another increase, this time amounting to the large figure of nearly 7 million gallons, an increase of nearly 57 per cent. The bulk of this oil was obtained from the 3,800-foot sand proved in the preceding year.

There was a slight decrease in the imports of kerosene, due to decreases in the imports from Persia (10 millions), Sumatra (2

millions) and Borneo (12½ millions), not quite balanced by increases from Russia (including Georgia), the Straits Settlements, the United States of America and other countries. Imports from the United States of America, which fell from over 60¼ million gallons in 1927 to not quite 17 million gallons in 1928, recovered slightly to 23½ million gallons. The increase from the Straits Settlements amounted to nearly 9 million gallons.

The quantity of fuel oil imported into India during 1929 was, as Table 25 will show, over 14 million gallons more than that received during the previous year, the total imports for the year under review being a little under 115 million gallons. Over three-quarters of the supply was derived from Persia and the greater part of the rest from Borneo.

The export of paraffin was again increased to the extent of over 14,000 tons more than it was during the previous year (see Table 26).

TABLE 23.—*Quantity and value of Petroleum produced in India during the years 1928 and 1929.*

——	1928.			1929.		
	Quantity.	Value (£1 = Rs. 13·4).		Quantity.	Value (£1 = Rs. 13·4).	
	Gals.	Rs.	£	Gals.	Rs.	£
Assam—						
Badarpur . .	2,730,576	7,12,324	53,159	2,036,275	5,09,069	37,990
Digboi . . .	28,745,982	49,08,624	366,315	31,497,054	53,78,403	401,373
Masimpur . .	25,780	6,725	501	5,360	1,340	100
Burma—						
Akyab . . .	5,260	2,428	181	1,980	914	68
Kyaukpyu . .	15,227	14,325	1,069	15,031	13,690	1,022
Minbu . . .	6,101,822	11,44,091	85,380	5,815,252	12,41,708	92,672
Singu . . .	113,986,786	2,13,72,513	1,594,964	91,481,726	1,94,39,867	1,450,736
Thayetmyo . .	727,322	1,37,623	10,270	746,221	1,58,572	11,884
Upper Chindwin .	2,308,880	1,73,166	12,923	2,796,560	2,09,742	15,652
Yenangyat . .	3,072,222	5,76,041	42,988	17,606,935	37,59,710	280,575
Yenangyaung . .	135,969,794	2,56,98,986	1,917,835	134,936,816	2,88,10,684	2,150,051
Punjab—						
Attock . . .	12,254,160	30,63,540	228,622	19,208,880	48,02,220	358,375
TOTAL .	305,943,711	*5,78,10,386*	*4,314,207*	[illegible]	*6,43,26,009*	*4,800,448*

TABLE 24.—*Imports of Kerosene Oil into India during the years 1928 and 1929.*

—	1928.			1929.		
	Quantity.	Value (£1 = Rs. 13·4).		Quantity.	Value (£1 = Rs. 13·4).	
	Gals.	Rs.	£	Gals.	Rs.	£
From—						
Russia . . .	14,169,538	79,20,185	591,055	12,778,434	65,73,605	490,568
Georgia . . .	20,515,333	99,78,065	744,259	25,801,615	1,34,93,605	1,006,985
Persia . . .	33,530,028	1,68,33,786	1,256,249	23,321,758	1,19,18,640	889,451
Straits Settlements (including Labuan).	73,730	43,586	3,249	9,020,855	47,23,576	352,506
Sumatra . . .	2,074,130	11,87,178	88,595	..	..	..
Borneo . . .	15,152,333	78,55,377	586,222	2,770,200	15,96,922	119,173
United States of America.	16,954,999	1,15,59,044	862,615	23,549,135	1,43,87,465	1,073,691
Other countries .	1,969,880	5,96,200	44,498	6,563,556	38,43,717	286,845
TOTAL .	104,439,966	*5,59,68,271*	*4,176,737*	03,800,553	*5,65,37,530*	*4,219,319*

TABLE 25.—*Imports of Fuel Oils into India during the years 1928 and 1929.*

—	1928.			1929.		
	Quantity.	Value (£1 = Rs. 13·4).		Quantity.	Value (£1 = Rs. 13·4).	
	Gals.	Rs.	£	Gals.	Rs.	£
From—						
Persia . . .	81,826,295	1,50,78,127	1,125,238	88,735,580	1,67,17,599	1,247,582
Straits Settlements (including Labuan).	4,713,687	16,85,345	125,772	10,831,396	22,13,486	165,185
Borneo . . .	14,140,215	35,28,120	263,292	15,796,600	31,60,087	235,824
Other countries .	288,260	81,052	6,049	102,444	18,505	1,381
TOTAL .	10[illegible],91[illegible],[illegible]57	*2,03,72,644*	*1,520,346*	114,[illegible]	*2,21,09,627*	*1,649,972*

TABLE 26.—*Exports of Paraffin Wax from India during the years 1928 and 1929.*

—	1928.			1929.		
	Quantity.	Value. (£1 = Rs. 13·4).		Quantity.	Value. (£1 = Rs. 13·4).	
	Tons.	Rs.	£	Tons.	Rs.	£
To—						
United Kingdom	11,511	53,22,111	397,172	21,534	1,05,73,410	789,061
Germany	3,227	15,03,519	112,203	2,818	13,08,705	97,665
Netherlands	5,492	25,07,960	187,161	5,037	23,01,319	171,740
Belgium	5,717	25,47,836	190,137	4,845	22,98,100	171,500
China	4,734	22,03,066	164,408	1,635	7,63,177	56,953
Union of South Africa	2,179	10,05,830	75,062	1,934	9,03,163	67,400
Portuguese East Africa.	2,789	16,93,133	126,353	3,351	22,21,721	165,800
United States of America.	4,065	18,49,575	138,028	7,518	34,21,060	255,303
Australia	914	4,16,778	31,103	1,179	5,45,158	40,683
New Zealand	351	1,59,705	11,918	71	32,532	2,428
Other countries	8,697	39,67,581	296,088	14,084	66,34,087	495,081
TOTAL	**49,676**	*2,31,77,094*	*1,729,633*	**64,006**	*3,10,02,432*	*2,313,614*

Ruby, Sapphire and Spinel.

A severe decline in the output from the Mogok ruby mines of Upper Burma in 1924, followed in 1925 by a marked drop in value, bore witness to a serious decline in the industry. The Burma Ruby Mines, Limited, ultimately decided to go into liquidation, and the mines were offered for sale in September, 1926. The skeleton organisation left in charge of the mines, however, made good use of its opportunities with the result that the value of the output in 1926 exceeded that of the previous year by over a lakh of rupees. This encouraging result was effected by a rigorous economy and an extension of a system of co-operation with local miners, and was assisted by some good finds of sapphires in the Kyaungdwin mine—the only one still worked by European methods.

During 1927, however, production fell in value by over 1¾ lakhs of rupees, due mainly to a decrease in the value of the sapphires and spinels produced, there having been a slight increase in the value of the rubies. During 1928, there was another very large

decline in value, amounting to over a lakh of rupees, due to a severe drop in the value of the sapphires produced; as before, there was a slight increase in the value of the rubies. The value of the 1929 production was slightly above that of 1928, due to a considerable increase in the value of the rubies found, largely balanced by another large fall in the value of sapphires produced.

The production of 'corundum with sapphire patches' in Kashmir during 1928 amounted to 1 cwt. only. The production in 1927 amounted to 11 cwts. and in 1926 to 1·6 cwts. The value in each case was not stated.

TABLE 27.—*Quantity and value of Ruby, Sapphire and Spinel produced in India during the years 1928 and 1929.*

—	1928.			1929.		
	Quantity.	Value (£1 = Rs. 13·4).		Quantity.	Value (£1 = Rs. 13·4).	
	Carats.	Rs.	£	Carats.	Rs.	£
Burma	32,010 (Rubies)	1,22,181	9,118	37,640 (Rubies)	1,70,426	12,718
	4,500 (Sapphires)	54,853	4,093	2,580 (Sapphires)	10,992	820
	3,870 (Spinels)	478	36	3,480 (Spinels)	342	26
Total	**40,380**	*1,77,512*	*13,247*	**43,650**	*1,81,760*	*13,564*

Salt.

There was a substantial increase in the total output of salt amounting to 193,752 tons, the three chief contributors to the increase being Aden, Bombay and Sind, and Northern India (146,135 tons). There was a small increase from Burma. Madras showed a decrease of 27,330 tons.

TABLE 28.—*Quantity and value of Salt produced in India during the years 1928 and 1929.*

—	1928.			1929.		
	Quantity.	Value (£1 = Rs. 13·4).		Quantity.	Value (£1 = Rs. 13·4).	
	Tons.	Rs.	£	Tons.	Rs.	£
Aden	222,771	18,66,844	139,317	246,243	17,03,958	127,161
Bombay and Sind	460,873	25,82,690	192,738	509,884	29,79,094	222,320
Burma	21,822	5,17,226	38,599	23,825	6,41,092	47,843
Gwalior (*a*)	60	3,107	232	21	1,031	77
Madras	448,538	26,36,046	196,720	421,208	24,86,220	185,539
Northern India	361,783	23,89,079	178,289	507,918	35,03,570	261,460
Total	**(b)1,515,847**	*99,94,992*	*745,895*	**(b)1,709,099**	*1,13,14,965*	*844,400*

(*a*) Figures relate to official years 1928-29 and 1929-30.
(*b*) Excludes the production of 2 tons in 1928 and 1 ton in 1929 in Kashmir State.

TABLE 29.—*Quantity and value of Rock-salt produced in India during the years 1928 and 1929.*

—	1928.			1929.		
	Quantity.	Value (£1 = Rs. 13·4).		Quantity.	Value (£1 = Rs. 13·4).	
	Tons.	Rs.	£	Tons.	Rs.	£
Salt Range	131,730	7,83,794	58,492	155,393	10,29,995	76,865
Kohat	19,812	63,276	4,722	19,625	63,068	4,707
Mandi	3,811	91,494	6,828	3,284	1,00,023	7,464
Total .	**155,353**	*9,38,564*	*70,042*	**178,302**	*11,93,086*	*89,036*

TABLE 30.—*Imports of Salt into India during the years 1928 and 1929.*

—	1928.			1929.		
	Quantity.	Value (£1 = Rs. 13·4).		Quantity.	Value (£1 = Rs. 13·4).	
	Tons.	Rs.	£	Tons.	Rs.	£
From—						
United Kingdom .	76,238	22,44,002	167,463	72,863	17,55,579	131,013
Germany . . .	62,499	17,05,071	127,244	60,786	14,34,758	107,071
Spain	67,979	17,25,810	128,792	54,871	11,07,026	82,614
Aden and Dependencies	201,167	49,04,564	366,012	220,415	43,57,963	325,221
Egypt	112,713	27,32,158	203,892	104,225	21,39,687	159,678
Italian East Africa .	55,505	13,04,626	97,360	57,030	11,27,672	84,155
Other countries . .	38,196	8,17,298	60,992	37,406	7,26,820	54,240
Total .	**614,297**	*1,54,33,529*	*1,151,755*	**607,596**	*1,26,49,505*	*943,992*

Saltpetre.

Although statistics of production of saltpetre in India are no longer available, the export figures may be accepted as a fairly reliable index to the general state of the industry. Excepting a few hundreds of tons required for internal consumption as fertiliser, most of the output is exported to foreign countries. The quantity exported in 1929 amounted to 91,708 cwts. valued at Rs. 9,61,051

(£71,720), against 89,570 cwts. valued at Rs. 10,00,034 (£74,629) in 1928.

A certain amount of nitrate of potash is used for agricultural purposes on the tea gardens of India. During the war when it was impossible to obtain supplies of imported potash, the amount of locally produced nitrate utilised in this way reached an appreciable figure. The practice continued and the quantities estimated to have been absorbed for fertilising purposes on tea gardens in 1923, 1924, 1925, 1926, 1927 and 1928 were 1,000, 1,100, 800, 700, 500, and 250 tons respectively. In 1929, this figure is estimated to have been 300 tons only. The gradual decrease since the year 1925 is due to the fact that it is found cheaper to employ a mixture of imported sulphate of ammonia and muriate of potash.[1]

TABLE 31.—*Distribution of Saltpetre exported from India during the years 1928 and 1929.*

—	1928.			1929.		
	Quantity.	Value (£1 = Rs. 13·4).		Quantity.	Value (£1 = Rs. 13·4).	
	Cwts.	Rs.	£	Cwts.	Rs.	£
To—						
United Kingdom . .	16,224	1,95,848	14,578	26,054	2,93,854	21,929
Ceylon	62,630	6,04,892	45,141	59,711	5,66,286	42,260
Straits Settlements (including Labuan).	2,868	44,427	3,316	2,235	29,008	2,165
Mauritius and Dependencies	6,084	1,14,680	8,558	2,544	50,880	3,797
Other countries . .	1,764	40,687	3,036	1,164	21,023	1,569
Total .	89,570	*10,00,034*	*74,629*	91,703	*9,61,051*	*71,720*

Silver.

In contrast with the increases in the production of silver from the Bawdwin mines of Upper Burma, amounting to 1,400,291 ozs. recorded during the previous four years, 1929 was marked by a decrease amounting to 124,211 ozs. The output of silver obtained as a bye-product from the Kolar gold mines of Mysore decreased to the extent of 3,272 ozs.

[1] From information kindly supplied by Messrs. Shaw, Wallace & Co.

TABLE 32.—*Quantity and value of Silver produced in India during the years 1928 and 1929.*

—	1928.			1929.		
	Quantity.	Value (£1 = Rs. 13·4).		Quantity.	Value (£1 = Rs. 13·4).	
	ozs.	Rs.	£	ozs.	Rs.	£
Burma—						
Northern Shan States .	7,404,728	1,19,26,055	890,004	7,280,517	1,07,31,482	800,857
Mysore—						
Kolar . . .	21,082	32,916	2,456	17,810	25,15	1,877
Total .	7,425,810	*1,19,58,971*	*892,460*	7,298,327	*1,07,56,637*	*802,734*

Tin.

A considerable increase in the production of tin-ore in Burma has to be reported for the year under review, during which the output amounted to 3,784·5 tons valued at Rs. 59,97,401 (£447,567), against 2,780 tons, valued at Rs. 45,41,201 (£338,895), in the preceding year. This increase of 1,004·5 tons is somewhat fictitious, as the figures for 1928 did not include 218 tons of low-grade complex wolfram-scheelite-cassiterite-ore recovered from the mine dumps of Mawchi in the Southern Shan States, and purchased from tributors for £4,018. No milling operations were performed, and the percentage composition of the mixed ore was therefore not precisely known. The figure for 1929 includes 371·3 tons from Mawchi, calculated to be the proportion of tin-ore in 651·5 tons of concentrates derived from mixed wolfram-scheelite-cassiterite-ore , these concentrates were assumed to contain 43 per cent. of wolfram and 57 per cent. of cassiterite. There is no reported output of block tin.

Imports of unwrought tin decreased slightly from 56,316 cwts. valued at Rs. 92,22,619 (£688,255) in 1928 to 55,358 cwts. valued at Rs. 80,95,974 (£604,177) in 1929; over 95 per cent. of these imports came from the Straits Settlements. Wrought tin, to the extent of 111 cwts. valued at Rs. 19,366 (£1,445), was also imported into India during the year under review.

TABLE 33.—*Quantity and value of Tin-ore produced in India during the years 1928 and 1929.*

—	1928.			1929.		
	Quantity.	Value (£1 = Rs. 13·4).		Quantity.	Value (£1 = Rs. 13·4).	
	Tons.		£	Tons.	Rs.	£
Burma—						
Amherst	9	10,917	815	40·2	60,136	4,488
Mergui	1,052	19,05,857	142,228	1,184·0	20,09,782	149,984
Southern Shan States .	..	..	..	371·3	(a) 5,88,399	43,910
Tavoy	1,712	26,15,122	195,158	2,170·9	33,11,751	247,145
Thaton	7	9,305	694	18·1	27,833	2,040
Total .	2,780	*45,41,201*	*338,895*	3,784·5	*59,97,401*	*447,567*

(a) Estimated.

TABLE 34.—*Imports of unwrought Tin (blocks, ingots, bars and slabs) into India during the years 1928 and 1929.*

—	1928.			1929.		
	Quantity.	Value (£1 = Rs. 13·4).		Quantity.	Value (£1 = Rs. 13·4).	
	Cwts.	Rs.	£	Cwts.	Rs.	£
From—						
United Kingdom . .	1,231	2,03,419	15,180	1,322	2,08,261	15,542
Straits Settlements (including Labuan).	54,205	88,85,003	663,060	52,962	77,26,405	576,598
Other countries . .	880	1,34,197	10,015	1,074	1,61,308	12,037
Total .	56,316	*92,22,619*	*688,255*	55,358	*80,95,974*	*604,177*

Tungsten.

During the past three years there has been a fall in the output of wolfram from 1,484 tons in 1926 to 622 tons in 1928, the last being valued at Rs. 299,549 (£22,354). A little over 218 tons of

low-grade complex wolfram-scheelite-cassiterite-ore, recovered from the mine dumps of Mawchi in the Southern Shan States of Burma and purchased from tributors for £4,018, have been omitted from the figure for 1928, since no milling operations were undertaken and the percentage composition of the mixed ore is not precisely known. The figure for 1929 includes 280·2 tons from Mawchi, calculated to be the proportion of wolfram in 651·5 tons of concentrates (assumed to contain 43 per cent. of wolfram and 57 per cent. of cassiterite) derived from the mixed wolfram-scheelite-cassiterite-ore. In 1929, the output rose again to 1,348·4 tons valued at Rs. 15,16,795 (£113,193).

The output of Tavoy recovered from 593 tons in 1928 valued at Rs. 2,87,852 (£21,481), to 1,010·8 tons in 1929 valued at Rs. 11,75,240 (£87,704). This increase in the value per ton of the production for 1929 is a reflection of a great increase in the market price of wolfram per unit, which rose from 14 shillings 6 pence per unit at the beginning of 1928 to 19 shillings at the end of that year and 33 to 35 shillings at the end of 1929.

TABLE 35.—*Quantity and value of Tungsten-ore produced in India during the years 1928 and 1929.*

—	1928.			1929.		
	Quantity.	Value (£1 = Rs. 13·4).		Quantity.	Value (£1 = Rs. 13·4).	
	Tons.	Rs.	£	Tons.	Rs.	£
Burma—						
Mergui	29	11,697	873	50·4	21,990	1,641
Southern Shan States .	..	..	..	(*a*)280·2	3,15,197	23,522
Tavoy	593	2,87,852	21,481	1,010·8	11,75,240	87,704
Thaton	..	..	..	7·0	4,368	326
Total .	622	*2,99,549*	*22,354*	1,348·4	*15,16,795*	*113,193*

(*a*) Estimated.

Zinc.

The production of zinc concentrates by the Burma Corporation, Limited, in the Northern Shan States, fell from 64,122 tons valued at Rs. 74,96,118 (£559,412) in 1928 to 58,435 tons valued at Rs. 54,80,034 (£408,958) in 1929. The exports during the year under review amounted to 67,408 tons valued at Rs. 68,00,930 (£507,532) against 76,031 tons valued at Rs. 74,10,889 (£553,051) in the preceding year.

Zircon.

The output of zircon, a mineral obtained as a concurrent product in the collection of ilmenite and monazite in Travancore State, increased from 855·2 tons valued at £4,267 in 1928 to 1,473 tons valued at £10,805 in 1929, in spite of a small decrease in the production of ilmenite.

III.—MINERALS OF GROUP II.

Agate.

The agate mines of Rajpipla State, Bombay Presidency, which had not been worked since 1917, were the source in 1929 of an output of 148·7 cwts. valued at Rs. 8,000 (£597).

Alum.

The output of alum in the Mianwali district, Punjab, amounted to only 478 cwts. valued at Rs. 5,525 (£412) in 1928, whilst in 1929 there was no manufacture owing to the low market rate.

Amber.

The production of amber in the Myitkyina district, Burma, decreased from 29·5 cwts. valued at Rs. 12,020 (£897) in 1928 to 19·6 cwts. valued at Rs. 6,080 (£454) in 1929.

Apatite.

The production of apatite in the Singhbhum district, Bihar and Orissa, was 805 tons valued at Rs. 14,490 (£1,081) in 1928. In 1929 there was no production from Singhbhum, but there was an output in the Trichinoply district, Madras, of 22 tons of apatite valued at Rs. 202 (£15).

Asbestos.

There was an increase in the total production of asbestos which amounted to 318·4 tons valued at Rs. 16,160 (£1,206) in 1929, against 156·5 tons valued at Rs. 21,735 (£1,622) in 1928. 80 tons were produced in the Seraikela state of Bihar and Orissa, 88·4 tons in the Cuddapah district, Madras, and 150 tons in the Hassan district of Mysore. The value of the asbestos from the Cuddapah district, which is reported as being of the first quality, has probably been greatly underestimated.

Barytes.

Of the total production of 3,750 tons of barytes valued at Rs. 22,739 (£1,697), 802 tons were produced in the Kurnool district, Madras, and 2,948 tons in the Alwar state, Rajputana. The production in 1928 amounted to 3,096 tons valued at Rs. 19,610 (£1,463).

Bauxite.

There was a large decrease in the total production of bauxite, which fell from 14,667 tons valued at Rs. 94,253 (£7,034) in 1928 to 9,044 tons valued at Rs. 72,352 (£5,399) in 1929. 9,044 tons were produced in the Kaira district of Bombay, but there was no production in the Jubbulpore district of the Central Provinces.

Beryl.

In Jaipur State, Rajputana, 40 cwts. of beryl were extracted: no value has been reported.

Bismuth.

The production of native bismuth from the Tavoy district, Burma, rose from slightly from 82 lbs. valued at Rs. 267 (£20) in 1928 to 88 lbs. valued at Rs. 308 (£23) in 1929.

Borax.

Borax is produced from the Puga valley in the Ladakh *tahsil* of Kashmir state. The production amounted to 7·3 cwts. valued at Rs. 23 (£1·7) in 1929, against 15 cwts. valued at Rs. 22 (£1·6) in 1928.

Building materials and road-metal.

The total estimated value of building materials and road-metal produced in the year under consideration was Rs. 1,50,21,820 (£1,121,032). Certain returns supplied in cubic feet have been converted into tons on the basis of certain assumed relations between volume and weight. The total production of 3,352,442 tons of limestone and *kankar* includes the production of 24,358 tons of dolomite produced in the Gangpur state, Bihar and Orissa, mainly for use as flux in the iron and steel industry; and 206 tons in the Jaisalmer state, Rajputana, used for building purposes (*see* Table 36).

TABLE 36.—*Production of Building Materials*

—	Granite and Gneiss. Quantity.	Granite and Gneiss. Value.	Laterite. Quantity.	Laterite. Value.	Lime. Quantity.	Lime. Value.	Limestone and Kankar. Quantity.	Limestone and Kankar. Value.
	Tons.	Rs.	Tons.	Rs.	Tons.	Rs.	Tons.	Rs.
Assam	30,302	41,158	28,665	51,631	..	..	60,724	87,071
Bengal	100,206	73,796	..	..	..	..	..	..
Bihar and Orissa	251,544	2,66,282	3,821	4,073	..	..	(a)889,499	18,41,128
Bombay	..	..	5,140	4,820	..	..	224,850	1,99,188
Burma	631,273	14,34,323	254,123	3,65,480	..	..	239,760	4,88,625
Central India	..	..	..	..	21,860	2,23,138	123,274	69,450
Central Provinces	30	135	2,738	6,253	..	..	447,802	6,00,121
Delhi	..	..	..	..	..	..	..	..
Gwalior	..	..	..	..	..	..	..	..
Kashmir	..	..	..	..	..	..	..	..
Madras	10,817	6,760	73,568	81,231	..	..	18,375	17,750
Mysore	..	..	6,798	6,055	9,714	1,56,571	22,268	36,430
N.-W. F. Province	..	..	..	..	..	..	1,061	780
Punjab	..	..	..	..	..	..	409,305	5,25,936
Rajputana	..	..	..	..	..	..	(b)106,077	3,03,794
United Provinces	..	..	..	..	..	..	(c)718,588	5,80,041
Total	**1,024,172**	*18,22,454*	**374,853**	*5,19,058*	**31,574**	*3,79,709*	[illegible]	*47,59,314*

(a) Includes 24,858 tons of dolomite.
(b) Includes 206 tons of dolomite.
(c) Includes 704,385 tons of *kankar* used for metalling roads.

and Road-metal in India during 1929.

MARBLE.		SANDSTONE.		SLATE.		TRAP.		MISCELLANEOUS.		Total Value (£1 = Rs. 13·4).	
Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.		
Tons.	Rs.	Tons.	Rs.	Tons.	Rs.	Tons.	Rs.	Tons.	Rs.	Rs.	£
..	..	12,885	36,856	..	..	..	..	251,154	4,72,068	6,88,784	51,402
..	..	..	..	..	..	..	..	..	..	73,796	5,507
..	..	30,029	56,788	48,090	1,22,493	32,005	2,52,007	194,006	2,32,337	27,75,108	207,098
..	..	8,900	14,300	..	..	624,341	8,77,330	1,147,462	6,82,740	17,77,878	132,677
..	..	309,554	6,45,744	..	..	..	..	695,879	10,04,207	39,38,388	293,910
..	..	5,985	50,004	..	..	..	..	109	39	3,42,631	25,570
..	..	13,900	15,810	..	..	..	..	60,587	44,342	6,75,661	50,423
..	..	..	..	..	..	..	..	37,500	43,750	43,750	3,265
..	..	28,845	49,798	..	..	..	..	..	..	49,798	3,716
..	..	..	..	..	..	..	..	286	94	94	7
..	..	..	..	..	..	..	..	167,393	2,08,176	3,13,917	23,427
..	..	..	..	..	..	..	..	160,150	2,83,133	4,82,180	35,984
..	..	..	..	..	..	..	..	..	..	780	58
..	..	..	..	5,555	1,36,994	..	..	368,095	4,83,362	11,46,202	85,544
5,800	2,19,625	174,114	4,34,178	180	750	..	..	14,427	24,165	9,82,412	73,314
..	..	40,398	47,126	327	1,293	..	..	624,614	11,01,882	17,30,348	129,130
5,800	*2,19,625*	**633,619**	*13,50,604*	**54,161**	*2,61,530*	**656,346**	*11,29,337*	**3,781,668**	*45,80,295*	**1,50,21,880**	*1,121,032*

There was an increase in the recorded production of clays, which rose from 185,576 tons valued at Rs. 4,24,180 (£31,655) in 1928 to 363,828 tons valued at Rs. 5,44,524 (£40,636). The major portion of this increase is from the Central Provinces, Mysore and the Punjab.

Clays.

TABLE 37.—*Production of Clays in India during the year 1929.*

—	1929.		
	Quantity.	Value (£1=Rs. 13·4).	
	Tons.	Rs.	£
Bengal	35,964	73,177	5,461
Bihar and Orissa	27,131	2,67,203	19,941
Burma	28,026	38,009	2,836
Central India	938	3,126	233
Central Provinces	119,227	54,428	4,062
Delhi	2,310	1,560	116
Gwalior	445	3,185	238
Madras	20,106	2,058	153
Mysore	88,219	95,138	7,100
Punjab	39,079	5,088	380
Rajputana	2,383	1,552	116
Total	363,828	*5,44,524*	*40,636*

The production of sulphate of iron in Ladakh, Kashmir State, fell from 3·3 cwts. valued at Rs. 6 (£0·4) in 1928 to *nil* in 1929.

Copperas.

The production of corundum in the Salem district, Madras, amounted to 34 tons valued at Rs. 4,080 (£304). There was no production reported from the Bhandara district of the Central Provinces. (*See* also under 'Ruby, Sapphire and Spinel').

Corundum.

The reported production of Fuller's earth rose from 3,394 tons in 1928 to 24,874 tons in 1929. Hyderabad (Sind) was responsible for a large increase, amounting to 22,611 tons, from nothing, set off by a fall from 1,836 tons to nothing from Bikaner.

Fuller's Earth.

TABLE 38.—*Quantity and value of Fuller's Earth produced in India during the years 1928 and 1929.*

—	1928.			1929.		
	Quantity.	Value (£1 = Rs. 13·4).		Quantity.	Value (£1 = Rs. 13·4).	
	Tons.	Rs.	£	Tons.	Rs.	£
Bombay—						
Hyderabad (Sind) . .	..	..	..	22,611	7,066	527
Central Provinces—						
Jubbulpore . . .	76	374	28	63	309	23
Mysore	457	559	42	695	(*a*)	..
Rajputana—						
Bikaner State . . .	1,836	11,020	822	..	..	..
Jaipur State . . .	..	..	..	85	500	38
Jaisalmer State . . .	25	351	26	20	310	23
Jodhpur State . . .	1,000	12,509	934	1,400	17,500	1,306
Total .	3,394	*24,813*	*1,852*	24,874	*25,685*	*1,917*

(*a*) Not-available.

Garnet. There was no production of garnet sand during the year, against 480 tons valued at Rs. 1,200 (£90) in 1928, reported from the Tinnevelly district, Madras.

Graphite. There was an output of 39 tons of graphite valued at Rs. 1,163 (£87) in Ajmer-Merwara, Rajputana.

Gypsum. There was a small fall in the output of gypsum from 59,050 tons valued at Rs. 1,46,322 (£10,919) in 1928 to 52,726 tons valued at Rs. 1,17,702 (£8,784) in 1929. The effect of gypsum in small quantities upon crops—a common application is 2 *maunds* to the acre—is said to be remarkable and its usefulness to the monsoon crops of southern Bihar has been experimentally demonstrated.[1] The Department of Agriculture, Bihar and Orissa, is importing annually increasing amounts of gypsum from Jamsar in Bikaner. The experimental work may,

[1] D. Clouston. Review of Agricultural Operations in India, 1924.

therefore, ultimately result in a demand from agricultural districts for gypsum.

TABLE 39.—*Quantity and value of Gypsum produced in India during the years 1928 and 1929.*

—	1928.			1929.		
	Quantity.	Value (£1 = Rs. 13·4).		Quantity.	Value (£1 = Rs. 13·4).	
	Tons.	Rs.	£	Tons.	Rs.	£
Baroda State . . .	257	1,531	114	..	..	..
Kashmir State . . .	82	86	6	49	50	4
Madras—						
Trichinopoly . . .	..	..	..	23	248	18
Punjab—						
Jhelum	17,971	28,848	2,153	16,163	23,364	1,744
Rajputana—						
Bikaner State . . .	25,597	74,873	5,588	21,846	54,380	4,058
Jaisalmer State . . .	143	859	64	145	860	64
Jodhpur State . . .	15,000	40,125	2,994	14,500	38,800	2,896
Total .	59,050	*1,46,322*	*10,919*	52,726	*1,17,702*	*8,784*

Miscellaneous refractory materials.

The production of kyanite amounted to 3,618 tons valued at Rs. 24,077 (£1,797) of which 3,518 tons were produced from the Lapso Hill mines in Kharsawan State and 100 tons from Mr. E. O. Murray's Ghagidih mines in the Singhbhum district, Bihar and Orissa. The production of quartzite, including quartz-kyanite-schist amounted to 27,527 tons valued at Rs. 72,446 (£5,406). There was no production of quartz-mica-schist. The total production of kyanite and quartzite amounted to 31,145 tons valued at Rs. 96,523 (£7,203) in 1929 against 31,425 tons valued at Rs. 85,226 (£6,360) in 1928.

Ochre.

There was a further increase in the production of ochre, which amounted to 7,362 tons valued at Rs. 54,877 (£4,095) in 1929 against 6,153 tons valued at Rs. 52,975 (£3,953) in 1928. This increase is chiefly due to an increased total output of 3,634 tons from the Panna state in Central India.

TABLE 40.—*Quantity and value of Ochre produced in India during the years 1928 and 1929.*

—	1928.			1929.		
	Quantity.	Value (£1 = Rs. 13·4).		Quantity.	Value (£1 = Rs. 13·4).	
	Tons.	Rs.	£	Tons.	Rs.	£
Central India	3,499	26,878	2,006	4,954	35,793	2,671
Central Provinces . . .	847	7,915	591	1,185	6,745	503
Gwalior	817	10,252	765	521	6,125	457
Madras	325	4,500	336	325	4,500	336
Rajputana	317	688	51	377	1,714	128
United Provinces . . .	348	2,742	204	..	..	..
Total .	6,153	*52,975*	*3,953*	7,362	*54,877*	*4,095*

Pyrite.

There was an output of 294 tons of pyrite in Patiala State, Punjab, in 1929, obtained in the course of prospecting operations. The value has not been reported.

Serpentine.

The figures of production of serpentine in the Skardu *tahsil*, Kashmir State, amounting to 1·8 tons valued at Rs. 75 (£6) reported for 1929, are identical with those for 1928.

Soda.

A production of 14·7 tons of soda valued at Rs. 533 (£40) was reported from the Ladakh *tahsil*, Kashmir State. The output for the previous year was 11 tons valued at Rs. 533 (£40). Salt, consisting for the greater part of sodium carbonate, sodium bicarbonate and sodium chloride, used to be obtained by evaporation from the waters of the Lonar lake, in the Buldana district of Berar, in the Central Provinces. It was known under the general name of *trona* or *urao*, for which there is no suitable equivalent in English. The total amount of *trona* extracted in 1926 was 100 tons, the value of which was estimated at 3,000 (£224); there was no subsequent production, as the company working the concession has gone into liquidation. There was a

production of 2·2 tons of crude soda (*rasi*) valued at Rs. 60 (£4) in Datia State, Central India, in the year under review.

Steatite.

There was an increase in the production of steatite, which rose from 5,539 tons valued at Rs. 1,30,070 (£9,706) in 1928 to 7,217 tons valued at Rs. 2,76,483 (£20,633) in 1929. The major portion of this large increase in value is due to the largely enhanced value of the output of Jaipur State, Rajputana.

TABLE 41.—*Quantity and value of Steatite produced in India during the years 1928 and 1929.*

—	1928.			1929.		
	Quantity.	Value (£1 = Rs. 13·4).		Quantity.	Value (£1 = Rs. 13·4).	
	Tons.	Rs.	£	Tons.	Rs.	£
Bihar and Orissa—						
Mayurbhanj	80	7,300	545	72	7,000	522
Seraikela	15	840	63	13	720	54
Singhbhum	346	7,706	575	349	11,491	858
Central India—						
Bijawar State	162	6,600	493	110	4,500	336
Central Provinces—						
Jubbulpore	1,284	23,281	1,737	1,541	24,506	1,829
Madras—						
Nellore	49	2,331	174	17	176	13
Salem	164	6,940	518	253	6,005	448
Mysore	88	264	20	60	300	22
Rajputana—						
Jaipur State	3,228	65,849	4,912	4,400	2,06,000	15,373
United Provinces—						
Hamirpur	119	8,629	644	412	15,785	1,178
Jhansi	4	330	25	..	..	..
Total	5,539	*1,30,070*	*9,706*	7,217	*2,76,483*	*20,633*

IV.—MINERAL CONCESSIONS GRANTED.

TABLE 42.—*Statement of Mineral Concessions granted during the year 1929.*

AJMER-MERWARA.

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Ajmer .	(1) S. Dhiraj Lal Porshetam, Nasirabad.	Mica . . .	P. L. (Renewal)	3·04	4th January 1929.	Up to 31st March 1929.
Do. .	(2) Do. .	Do. . . .	P. L. .	0·40	Do. .	Do.
Do. .	(3) L. Prag Narain .	Graphite . .	P. L. .	20·00	16th February 1929.	1 year.
Do. .	(4) Messrs. Abdul Ghani & Co.	Mica . . .	P. L. .	2·90	18th March 1929.	Do.
Do. .	(5) Mr. Nassarwanji D. Contractor.	Mica, beryl and acquamarine.	P. L. (Renewal).	2·00	22nd March 1929.	Do.
Do. .	(6) L. Goverdhan Lal Rathi.	Mica . . .	P. L. .	0·78	20th April 1929.	Do.
Do. .	(7) Messrs. Radha Kishen Kanahiya Lal.	Do. . . .	P. L. .	7·70	31st May 1929.	Do.
Do. .	(8) Do. .	Do. . . .	P. L. .	1·12	Do. .	Do.
Do. .	(9) Do. .	Do. . . .	P. L. .	0·72	25th June 1929.	Do.
Do. .	(10) Messrs. Abdul Ghani & Co.	Do. . . .	P. L. .	5·70	13th July 1929.	Do
Do. .	(11) Do. .	Do. . . .	P. L. .	1·30	2nd October 1929.	Do.
Do. .	(12) Mr. Nassarwanji D. Contractor.	Do. . . .	P. L. .	4·00	7th November 1929.	Do.
Do. .	(13) P. Kishen Lal Contractor.	Do. . . .	P. L. (Renewal).	3·88	2nd December 1929.	Do
Beawar .	(14) L. Prag Narain .	Do. . . .	P. L. .	3·20	19th April 1929.	Do.
Do. .	(15) Do. .	Do. . . .	P. L .	1·04	28th March 1929.	Do.
Do. .	(16) Mr. Krishna Mool Chand Kapoor.	Do. . . .	P. L. (Renewal).	6·50	17th August 1929.	Do.
Do. .	(17) Do. .	Do. . . .	P. L. .	1·64	Do. .	Do.
Do. .	(18) Mr. Mohamed Fazil.	Do. . . .	M. L. .	3·8	3rd August 1929	10 years.

P. L. = *Prospecting License.* M. L. = *Mining Lease.*

ASSAM.

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Cachar .	(19) The Burmah Oil Company, Limited.	Natural petroleum.	P. L. .	2,060·8	1st June 1929	2 years.
Do. . .	(20) Do. .	Mineral oil . .	P. L. . (Renewal).	1,088·0	3rd December 1929.	1 year.
Khasi and Jaintia Hills.	(21) The Khasia Sillimanite Co., Ltd.	Sillimanite . .	P. L. .	640·0	6th January 1929.	Do.
Do. .	(22) Do. .	Do. . .	P. L. .	640·0	Do. .	Do.
Lakhimpur .	(23) Assam Oil Co., Ltd.	Mineral oil . .	P. L. .	5,120 0	30th March 1929.	Do.
Do. .	(24) Do. .	Do. .	P. L. .	3,968·0	12th May 1929.	Do.
Do. .	(25) Do. .	Do. . .	P. L.	9,792·0	8th October 1929.	Do.
Do. .	(26) Do. .	Coal . . .	P. L. .	3,616·0	Do. .	Do.
Do. .	(27) Do. .	Mineral oil . .	P. L. .	1,792·0	25th July 1929.	Do.
Do. .	(28) Do. .	Do. . .	P. L. .	665·6	2nd May 1929	2 years.
Do. .	(29) Do. .	Do. . .	P. L. .	1,491·2	7th April 1928.	Do.
Do. .	(30) Do. .	Do. . .	P. L. .	720·0	20th April 1928.	Do.
Do. .	(31) Do. .	Do. . .	P. L. .	1,280·0	7th April 1928.	Do.
Manipur .	(32) G. O. Mansukhani	Copper . .	P. L. .	1,140·0	22nd August 1929.	1 year.
Sadiya Frontier Tract.	(33) Assam Oil Co., Ltd.	Oil . . .	P. L. .	2,240·0	19th December 1929.	2 years.
Sibsagar .	(34) The Burmah Oil Co., Ltd.	Mineral oil . .	P. L. .	3,488·0	26th April 1929.	1 year.
Do. .	(35) Do. .	Do. . .	P. L. .	6,656·0	10th September 1929.	Do.
Sylhet .	(36) Do. .	Do. . .	P. L. .	3,136·0	3rd May 1929	Do.
Do. .	(37) Do. .	Do. . .	P. L. .	3,161·6	3rd September 1929.	Do.
Do. .	(38) Do. .	Do. . .	P. L. .	9,305·6	1st October 1929.	Do.

BALUCHISTAN.

Sibi . .	(39) K. B. B. D. Patel	Coal and coal dust.	M. L. .	80	1st January 1929.	30 years.

P. L. = *Prospecting License.* M. L. = *Mining Lease.*

BENGAL.

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Chittagong .	(40) The Burmah Oil Co., Ltd.	Natural petroleum	P. L. . (Renewal).	4,000	9th March 1929.	1 year.

BIHAR AND ORISSA.

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Angul .	(41) Babu Dibakor Patnaik.	Red ochre . .	P. L. .	640·00	1st January 1929.	1 year.
Santal Parganas.	(42) Babu Rameswar Marwari Darji.	Coal . . .	M. L. .	5·00	1st April 1929	Do.
Do. .	(43) Babu Binode Behari De.	Do. . . .	M. L. .	2·15	Do. .	2 years.
Do. .	(44) Do. .	Do. . . .	M. L. .	1·90	Do. .	Do.
Do. .	(45) Babu Bansi Ram Marwari.	Do. . . .	M. L. .	1·90	Do. .	Do.
Do. .	(46) Do. .	Do. . . .	M. L. .	5·00	Do. .	Do.
Do. .	(47) Do. .	Do. . . .	M. L. .	0·33	Do. .	Do.
Do. .	(48) Do. .	Do. . . .	M. L. .	5·04	Do. .	Do.
Do. .	(49) Babu Ramrekh Das Himat Singka.	Do. . . .	M. L. .	5·00	Do. .	Do.
Singhbhum .	(50) Babu Dwarka Das Agarwala.	Iron-ore and manganese.	P. L. .	619·65	2nd February 1929.	1 year.
Do. .	(51) Babu Narendra Nath Kumar.	Chromite . .	M. L. .	596·30	Lease not yet executed.	10 years.
Do. .	(52) Babu Mangi Lal Marwari.	Do. . .	M. L. .	216·00	Do. .	Do.
Do. .	(53) Messrs. Visanji Umarsi & Co.	Iron-ore and manganese	P. L. .	665·60	24th June 1929.	1 year.
Do. .	(54) Babu Indra Singh	Do. .	P. L. .	1,932·80	3rd July 1929	Do.
Do. .	(55) Babu Dhanji Kumarji.	Chromite . .	P. L. .	640·00	26th June 1929.	Do.
Do. .	(56) Babu Mangi Lal Marwari.	Manganese . .	P. L. .	228·40	24th June 1929.	Do.
Do. .	(57) Babu Hira Lal Marwari.	Manganese and iron-ore.	P. L. .	1,612·80 .	20th December 1928.	Do.
Do. .	(58) Babu Dhanji Kumarji.	Do. .	P. L. .	537·60	26th June 1929.	Do.
Do. .	(59) Messrs. Visanji Umarsi & Co.	Manganese . .	M. L. .	40·00	15th June 1929.	Up to 26th January 1988.
Do. .	(60) Do. .	Iron-ore . .	M. L. .	27·25	5th September 1929.	Up to 29th August 1987.
Do. .	(61) Babu Dwarkadas Agarwalla.	Manganese . .	M. L. .	203·75	Do. .	10 years.

P. L. = Prospecting License. *M. L. = Mining Lease.*

BIHAR AND ORISSA—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Singhbhum .	(62) Babu Dwarkadas Agarwala.	Manganese and iron-ore.	M. L. .	960·00	5th September 1929.	20 years.
Do. .	(63) Babu Narendra Nath Kumar.	Chromite . .	P. L. .	1,528·32	5th November 1929.	1 year.
Do. .	(64) Babu Charu Chandra Mittra.	Manganese .	P. L. .	309·80	Do. .	Do.
Do. .	(65) Messrs. Tata Iron & Steel Co., Ltd.	Chromite . .	M. L. .	270·90	Lease not yet executed.	30 years.
Do. .	(66) Babu Hira Lal Marwari.	Iron-ore and manganese.	M. L. .	126·71	4th September 1929.	10 years.
Do. .	(67) Messrs. Tata Iron & Steel Co., Ltd.	Iron-ore . .	M. L. .	237·23	Lease not yet executed.	Up to 31st December 1951.
Do. .	(68) Do. .	Do. . .	P. L. .	1,491·20	License not yet executed.	1 year.
Do. .	(69) Babu Arjun Ladha	Iron-ore and manganese.	M. L. .	441·50	7th December 1929.	10 years.
Do. .	(70) Babu Mangi Lal Rungta.	Do. .	M. L. .	819·76	Not stated .	Do.
Do. .	(71) Mr. S. S. Guzdar.	All minerals except iron-ore and mica.	P. L. .	548·00	License not yet executed.	1 year.

BOMBAY.

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Belgaum .	(72) Mr. A. N. Peston Jamas.	Bauxite . .	P. L. .	60·0	6th November 1929.	4 month and 25 days.
Kanara .	(73) The Kanara Mining Syndicate, Bombay.	Manganese . .	P. L. .	1,708·4	19th June 1929.	1 year.
Do. .	(74) Mr. E. H. Rushton	Do. . .	P. L. .	642·0	8th March 1929.	Do.
Ratnagiri .	(75) Messrs. Oakley Duncan & Co., Ltd., Bangalore.	Chromite . .	P. L. .	1,280·0	30th January 1929.	Do.

BURMA.

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Akyab .	(76) Messrs. Indo-Burma Petroleum Co., Ltd.	Natural petroleum (including natural gas).	P. L. . (Renewal).	1,177·6	11th March 1929.	1 year.
Do. .	(77) Messrs. Burmah Oil Co., Ltd.	Do. .	P. L. . (Renewal)	5,056·0	9th May 1929	Do.
Do .	(78) Do. .	Do. .	P. L. . (Renewal).	4,352·0	Do. .	Do.

P. L. = *Prospecting License.* M. L. = *Mining Lease.*

BURMA—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Akyab .	(79) Messrs. Burmah Oil Co., Ltd.	Natural petroleum (including natural gas).	P. L. . (Renewal).	4,480·0	28th July 1929.	1 year.
Do. .	(80) Do. .	Do. .	P. L. . (Renewal).	1,280·0	2nd November 1928.	Do.
Do. .	(81) Messrs. Indo-Burma Petroleum Co., Ltd.	Do. .	P. L. . (Renewal).	5,440·0	15th February 1928.	Do.
Do. .	(82) Messrs. Burmah Oil Co., Ltd.	Do. .	P. L. . (Renewal).	633·6	30th July 1929.	Do.
Amherst .	(83) Mr. V. Palmgren.	All minerals except oil.	P. L. .	1,120·08	8th October 1929.	Do.
Do. .	(84) Mr. A. C. Jeewa .	Do. .	P. L. .	1,254·4	5th March 1929.	Do.
Do. .	(85) Maung Ba Bwa .	Do. .	P. L. .	640·0	7th March 1929.	Do.
Do. .	(86) Messrs. The Burma Mining Corporation, Ltd.	Do. .	P. L. .	1,620·6	7th August 1929.	Do.
Do. .	(87) Mr. J. A. Angus .	Do. .	P. L. .	2,560·0	13th November 1929.	Do.
Lower Chindwin.	(88) Messrs. Indo-Burma Petroleum Co., Ltd.	Natural petroleum (including natural gas).	P. L. . (Renewal).	5,760·0	5th July 1928	Do.
Do. .	(89) Do. .	Do. .	P. L. . (Renewal).	5,798·4	24th September 1928.	Do.
Do. .	(90) Do. .	Do. .	P. L. . (Renewal).	1,600·0	22nd September 1928.	Do.
Do. .	(91) Do. .	Do. .	P. L. . (Renewal)	19,200·0	30th July 1929.	Do.
Do. .	(92) Do. .	Do. .	P. L. . (Renewal).	5,760·0	5th July 1929	Do.
Do. .	(93) Do. .	Do. .	P. L. . (Renewal).	5,798·4	24th September 1929.	Do.
Do. .	(94) Messrs. Burmah Oil Co., Ltd.	Do. .	P. L. . (Renewal).	2,560·0	12th November 1928.	Do.
Do. .	(95) Do. .	Do. .	P. L. . (Renewal).	320·0	5th August 1929.	Do.
Do. .	(96) Mr. Lawrence Dawson.	Do. .	P. L. . (Renewal).	1,196·8	5th February 1929.	Do.
Magwe .	(97) Messrs. British Burma Petroleum Co., Ltd.	Do. .	P. L. .	5,440·0	1st April 1929	2 years.
Do. .	(98) Mr. A. Rahman .	Do. .	P. L. .	1,280·0	22nd July 1929.	1 year.
Do. .	(99) Messrs. Burmah Oil Co., Ltd.	Do. .	P . .	640·0	2nd September 1929.	Do.

P. L. = *Prospecting License.* M. L. = *Mining Lease.*

BURMA—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Magwe .	(100) Messrs. Burmah Oil Co., Ltd.	Natural petroleum (including natural gas).	P. L. .	320·0	8th December 1929.	1 year.
Do. .	(101) U. Thu Daw .	Do. .	P. L. .	1,600·0	15th October 1929.	Do.
Meiktila .	(102) Mr. J. W. Rayan	All minerals other than natural petroleum.	P. L. .	1,818·4	4th April 1929.	Do.
Do. .	(103) Do. .	All minerals except precious stone.	P. L. .	358·4	1st April 1929.	Do.
Do. .	(104) Do. .	All minerals other than mineral oil.	P. L. .	473·6	4th June 1929.	Do.
Mergui .	(105) Ma Kyin Mya and Ma Lin.	Tin and allied minerals except mineral oil.	P. L. .	601·6	27th March 1929.	Do.
Do. .	(106) Messrs. Tavoy Tin Dredging Corporation, Ltd.	Do. .	P. L. .	192·0	7th January 1929.	Do.
Do. .	(107) Mr. Eu Gwan Kyin.	Tin-ore . .	P. L. .	211·2	5th August 1929.	Do.
Do. .	(108) Messrs. Burma Alluvials Syndicate, Ltd.	Do. . .	P. L. .	179·2	21st January 1929.	Do.
Do. .	(109) Mr. E. B. Milne.	Do. . .	P. L. .	25·6	31st January 1929.	Do.
Do. .	(110) Mr. A. J. Beale.	Do. . .	P. L. .	2,048·0	22nd June 1929.	Do.
Do. .	(111) Mr. J. I. Milne .	Do. . . .	P. L. .	1,126·4	14th June 1929.	Do.
Do. .	(112) Do. .	Do. . .	P. L. .	480·0	25th March 1929.	Do.
Do. .	(113) Messrs. Burma Alluvials Syndicate, Ltd.	Do. . .	P. L. .	416·0	6th May 1929	Do.
Do. .	(114) Mr. H. N. Wilkins.	Tin and allied minerals except mineral oil.	P. L. .	198·4	2nd February 1929.	Do.
Do. .	(115) U. Shwe Yun .	Tin . . .	P. L. .	160·0	3rd January 1929.	Do.
Do. .	(116) S. H. Harman .	Tin-stone and allied minerals.	P. L. .	480·0	20th August 1929.	Do.
Do. .	(117) Do. .	Do. .	P. L. .	192·0	30th January 1929.	Do.
. .	(118) Do. .	Do. .	P. L. .	441·6	Do. .	Do.
Do. .	(119) Mr. Md. Haniff .	Tin-ore and other allied metals.	P. L. .	499·2	19th January 1929.	Do.
Do. .	(120) Mr. E. B. Milne.	Tin-ore . .	P. L. .	153·6	28th February 1929.	Do.

P. L. = *Prospecting License.*

BURMA—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Mergui .	(121) Mr. Edward Healey.	Tin and gold .	P. L. .	2,547·2	16th April 1929.	1 year.
Do. .	(122) Mr. Tan Sine Shin.	All minerals except oil.	P. L. .	83·2	14th March 1929.	Do.
Do. .	(123) Mr. A. S. Mahomed.	Tin-ore and other allied metals.	P. L. .	320·0	Do. .	Do.
Do. .	(124) Mr. E. B. Milne.	Tin . . .	P. L. .	192·0	31st May 1929.	Do.
Do. .	(125) Mr. Tan Boon Hein.	Do. . . .	P. L. .	128·0	9th December 1929.	Do.
Do. .	(126) Do. .	Do. . . .	P. L. .	460·8	9th July 1929	Do.
Do. .	(127) Messrs. Wightman & Co. (of Rangoon), Ltd.	All minerals other than petroleum and precious stones.	P. L. .	384·0	14th June 1929.	Do.
Do. .	(128) Mr. Tan Sine Shin.	Tin and allied minerals.	P. L. .	460·8	25th June 1929.	Do.
Do. .	(129) Messrs. Malayan and General Trust, Ltd.	Do. .	P. L. .	1,900·8	24th August 1929.	Do.
Do. .	(130) Dr. John Morrow Campbell.	All minerals except oil.	P. L. .	2,060·8	18th May 1929.	Do.
Do. .	(131) Messrs. Austral Malay Tin, Ltd.	Tin and allied minerals.	P. L. .	1,164·8	30th December 1929.	Do.
Do. .	(132) Messrs. Burma Alluvials Syndicate, Ltd.	Tin-ore and other metalliferous minerals.	P. L. .	134·4	24th July 1929.	Do.
Do. .	(133) Dr. San Moe .	Tin and allied minerals.	P. L. .	217·6	8th July 1929	Do.
Do. .	(134) Dr. John Morrow Campbell.	All minerals except oil.	P. L. .	76·8	17th May 1929.	Do.
Do. .	(135) Mr. E. Ahmed .	Tin-ore and other allied minerals.	P. L. .	384·0	12th September 1929.	Do.
Do. .	(136) Mr. B. B. Jubb.	Tin-ore . .	P. L. .	256·0	5th August 1929.	Do.
Do. .	(137) Mr. Tan Eik Kun	Do. . .	P. L. .	467·2	25th June 1929.	Do.
Do. .	(138) Mr. M. E. Maxwell Lefroy.	All minerals except oil and precious stones.	P. L. .	403·2	6th October 1929.	Do.
Do. .	(139) Do. .	Do. .	P. L. .	102·4	26th October 1929.	Do.
Do. .	(140) Maung San Dun	Tin . . .	P. L. .	128·0	24th July 1929.	Do.
Do. .	(141) Mr. B. B. Jubb.	Do. . . .	P. L. .	352·0	5th August 1929.	Do.
Do. .	(142) Mr. S. H. Harman.	All minerals except oil.	P. L. .	364·8	26th October 1929.	Do.

P. L. = *Prospecting License.*

BURMA—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Mergui .	(143) Mr. A. C. Martin	Tin and allied minerals.	P. L. .	684·8	16th November 1929.	1 year.
Do. .	(144) Mr. Khoo Tun Byan.	Cassiterite, wolfram and allied minerals.	P. L. .	396·8	30th September 1929.	Do.
Do. .	(145) Mr. Eng Tain Leong.	Tin-ore . .	P. L. .	537·6	26th October 1929.	Do.
Do. .	(146) Mr. F. L. Watts	Do. . .	P. L. .	352·0	9th November 1929.	Do.
Do. .	(147) Mr. Maung Kyin Bu.	Do. . .	P. L. .	326·4	30th September 1929.	Do.
Do. .	(148) Mr. W. C. Toms.	Do. . .	P. L. .	228·0	9th December 1929.	Do.
Do. .	(149) Mr. Kwee Ya .	Do. . .	P. L. .	435·2	21st December 1929.	Do.
Do. .	(150) Mr. Khoo Tun Byan.	Tin and allied minerals.	P. L. .	345·6	16th November 1929.	Do.
Do. .	(151) Mr. C. Ah Yaw .	Tin, wolfram and other allied metals.	P. L. .	454·4	30th December 1929.	Do.
Do. .	(152) Mr. B. C. P. Campbell.	Do. .	P. L.	1,824·0	21st December 1929.	Do.
Do. .	(153) Mr. Lim Shain .	Tin and wolfram.	M. L. .	390·4	22nd May 1929.	30 years.
Do. .	(154) Messrs. The Consolidated Tin Mines of Burma, Ltd.	Cassiterite . .	M. L. .	857·6	1st April 1929	Do.
Do. .	(155) Mr. E. Ahmed .	All minerals except natural petroleum and natural gas.	M. L. .	832·0	1st March 1929.	Up to the 7th August 1945.
Do. .	(156) Mr. A. H. Noyes	Tin and allied minerals.	M. L. .	371·2	1st May 1929	15 years.
Do. .	(157) Do. .	Do. .	M. L. .	83·2	Do. .	Do.
Do. .	(158) Do. .	Do. .	M. L. .	204·8	Do. .	Do.
Do. .	(159) Dr. Henry E. Wells.	Do. .	M. L. .	294·4	15th May 1929.	30 years.
Do. .	(160) Do. .	Do. .	M. L. .	505·6	1st May 1929	Do.
Do. .	(161) Mr. Ma Tin .	Do. .	M. L. .	544·0	16th June 1929.	Do.
Do. .	(162) Mr. J. I. Milne .	Tin-ore . .	M. L. .	460·8	1st May 1929	Do.
Do. .	(163) Mr. Ah Khoon .	Tin and allied minerals.	M. L. .	192·0	1st April 1929	Do.
Do. .	(164) Mr. Joo Seng .	Do. .	M. L. .	742·4	16th June 1929.	Do.
Do. .	(165) Mr. A. Asis .	Do. .	M. L. .	134·4	1st March 1929.	Do.

P. L. = *Prospecting License.* M. L. = *Mining Lease.*

BURMA—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Mergui .	(166) Maung Po .	Tin-ore . .	M. L. .	256·0	16th May 1929.	30 years.
Do. .	(167) Mr. M. A. Noordin.	Tin and allied minerals.	M. L. .	640·0	15th September 1929.	Do.
Do. .	(168) Mr. G. H. Hand.	Do. .	M. L. .	198·4	1st June 1929.	Do.
Do. .	(169) Mr. F. L. Watts.	Tin-ore . .	M. L. .	230·4	15th February 1929.	Do.
Do. .	(170) Mr. G. H. Hand.	Tin and allied minerals.	M. L. .	140·8	1st June 1929.	Do.
Do. . .	(171) Major J. W. Newbery.	Do. .	M. L. .	102·4	16th May 1929.	20 years.
Do. .	(172) Mr. Yoo Sain Guan.	Tin and allied minerals except mineral oil.	M. L. .	32·0	1st May 1929	30 years.
Do. .	(173) Mr. Leong Foke Hye.	Tin and allied minerals.	M. L. .	1,196·8	1st May 1929	Do.
Do. .	(174) Mr. Ah Sheo .	Do. .	M. L.	102·4	1st June 1929	Do.
Do. .	(175) Mr. G. H. Hand	Do. .	M. L. .	44·8	15th August 1929.	Do.
Do. .	(176) Maung Kin Bu .	Do. .	M. L. .	51·2	15th August 1929.	15 years.
Do. .	(177) Messrs. Austral Malay Tin, Ltd.	Tin oxide . .	M. L. .	19·2	9th March 1929.	22 years.
Do. .	(178) Mr. B. B. Jubb	Tin and allied minerals.	M. L. .	57·6	16th December 1929.	15 years.
Do. .	(179) Mr. S. Warwick Smith.	All minerals other than mineral oil.	P. L. . (Renewal).	89·6	7th January 1929.	1 year.
Do. .	(180) Ma Tin . .	Tin and allied minerals except mineral oil.	P. L. . (Renewal).	652·8	3rd February 1929.	Do.
Do. .	(181) Mr. Tan Boon Hein.	Do. .	P. L. . (Renewal).	149·6	21st April 1929.	Do.
Do. .	(182) Mr. Ah Sheo .	Tin-ore . .	P. L. . (Renewal).	128·0	17th March 1929.	Do.
Do. .	(183) Mr. Tan Eik Kun	Do. . .	P. L. . (Renewal).	332·8	27th June 1929.	Do.
Do. .	(184) Do. .	Do. . .	P. L. . (Renewal).	262·4	Do. .	Do.
Do. .	(185) Mr. Tan Sine Shin.	Tin and allied minerals except mineral oil.	P. L. . (Renewal).	217·6	8th June 1929.	Do.
Do. .	(186) Maung Po .	Do. .	P. L. . (Renewal).	326·4	18th April 1929.	Do.

P. L. = *Prospecting License.* M. L. = *Mining Lease.*

BURMA—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Mergui .	(187) Maung San Dun	Tin . . .	P. L. (Renewal).	390·4	21st August 1929.	1 year.
Do. .	(188) Mr. A. S. Mahomed.	Tin-ore and other allied metals except mineral oil.	P. L. (Renewal).	300·8	1st August 1929.	Do.
Do. .	(189) Messrs. Holmes and Morgan.	Do. .	P. L. (Renewal).	211·2	27th August 1929.	Do.
Do. .	(190) Mr. Leslie R. Beale.	Do. .	P. L. (Renewal).	473·6	8th September 1929.	Do.
Do. .	(191) Mr. Ah Shee .	Tin-ore . .	P. L. (Renewal).	288·0	18th October 1929.	Do.
Minbu .	(192) Mr. Lee Sa Baw	Coal . . .	P. L. .	2,560·0	7th May 1929	Do.
Myingyan .	(193) Messrs. The Yenangyaung Oilfield Southern Extension, Ltd.	Mineral oil . .	P. L. (Renewal).	1,280·0	27th September 1929.	Do.
Myitkyina .	(194) Messrs. The Tavoy Prospectors, Ltd.	All minerals except oil.	P. L. .	1,600·0	17th September 1929.	Do.
Do. .	(195) Do. .	Do. .	P. L. .	2,240·0	Do. .	Do.
Do. .	(196) Do. .	Do. .	P. L. .	1,600·0	Do. .	Do.
Do. .	(197) Do. .	Do. .	P. L. .	1,280·0	Do. .	Do.
Northern Shan States.	(198) Mr. A. R. Oberlander, Namtu.	Lead and silver-ore.	P. L. .	320·0	18th August 1929.	Do.
Do. .	(199) Do. .	Do. .	P. L. (Renewal).	1,920·0	20th March 1929.	Do.
Pakokku .	(200) Ma Bi Bi . .	Natural petroleum	P. L. .	499·2	15th October 1929.	Do.
Do. .	(201) Messrs. Burmah Oil Co., Ltd.	Do. .	P. L. .	320·0	24th April 1929.	2 years.
Do. .	(202) Do. .	Do. .	P. L. .	320·0	19th October 1929.	Do.
Do. .	(203) Messrs. Indo-Burma Petroleum Co., Ltd.	Do. .	P. L. .	2,400·0	12th February 1929.	Do.
Do. .	(204) Messrs. Rangoon Oil Co., Ltd.	Do. .	M. L. (Renewal).	640·0	1st January 1929.	30 years.
Do. .	(205) Messrs. Burmah Oil Co., Ltd.	Do. .	P. L. (Renewal).	800·0	7th November 1929.	1 year.
Do. .	(206) Messrs. Rangoon Oil Co., Ltd.	Do. .	M. L. (Renewal).	640·0	Not stated .	Not stated.
Do. .	(207) Messrs. Burmah Oil Co., Ltd.	Do. .	P. L. (Renewal).	160·0	22nd March 1929.	1 year.
Salween .	(208) Maung Thein San.	All minerals except mineral oil.	P. L. .	2,560·0	1st August 1929.	Do.

P. L. = *Prospecting License.* M. L. = *Mining Lease.*

BURMA—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Shwebo	(209) Messrs. The Indo-Burma Petroleum Co., Ltd.	Natural petroleum including natural gas.	P. L.	5,440·0	14th August 1929.	2 years
Do.	(210) Do.	Do.	P. L. (Renewal).	5,118·6	12th March 1929.	Do.
Southern Shan States.	(211) Messrs. Steel Bros.	Silver and lead	P. L.	473·6	16th May 1929.	1 year.
Do.	(212) Do.	Do.	P. L.	2,080·0	1st June 1929	Do.
Do.	(213) Maung Nyan	Slag	P. L.	550·4	Do.	Do.
Do.	(214) Mr. Tan Po Yin	Do.	M. L.	243 2	1st November 1929.	10 years.
Do.	(215) Mr. J. W. Ryan	Wolfram	P. L.	576·0	16th November 1929.	1 year.
Do.	(216) Messrs. Steel Bros.	Silver and lead	P. L.	643 6	3rd December 1929.	Do.
Do.	(217) Do.	Do.	P. L.	460·8	Do.	Do.
Do.	(218) Do.	Do.	P. L.	320·0	Do.	Do.
Do.	(219) Do.	Do.	P. L.	128·0	Do.	Do.
Do.	(220) Mr. Abdul Haq.	All minerals except oil.	P. L.	832·0	7th January 1929.	Do.
Do.	(221) Messrs. Steel Bros.	Silver and lead	P. L. (Renewal).	14,016·0	20th September 1929.	2 years.
Tavoy	(222) Maung Po Swe.	Tin and wolfram.	M. L.	640·0	1st April 1929.	30 years.
Do.	(223) Messrs. The Tavoy Rubber Co.	Do.	P. L.	684·8	20th August 1929.	1 year.
Do.	(224) Mr. A. J. Robertson.	Do.	P. L.	134·4	31st July 1929.	Do.
Do.	(225) Do.	Do.	P. L.	185·6	12th July 1929.	Do.
Do.	(226) Mr. Quah Hun Cheong.	Do.	P. L.	249·6	5th April 1929.	Do.
Do.	(227) Maung Ohn Nyun	Do.	P. L.	1,497·6	27th July 1929.	Do.
Do.	(228) Mr. S. N. Dutt.	Do.	P. L.	588·8	20th March 1929.	Do.
Do.	(229) Do.	Do.	P. L.	640·0	5th March 1929.	Do.
Do.	(230) Mr. A. J. Robertson.	Do.	P. L.	640·0	22nd July 1929.	Do.
Do.	(231) Mr. S. N. Dutt.	Do.	P. L.	819·2	30th August 1929.	Do.
Do.	(232) Mr. A. C. Martin	Do.	P. L.	889·6	29th August 1929.	Do.

P. L. = *Prospecting License.* M. L. = *Mining Lease.*

BURMA—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Tavoy .	(233) Mr. C. Soo Don.	Tin and wolfram .	P. L. .	640·0	21st March 1929.	1 year.
Do. .	(234) Ma Thein May .	Do. .	P. L. .	640·0	5th April 1929.	Do.
Do. .	(235) Mr. J. J. A. Page	Do. .	P. L. .	51·2	4th June 1929.	Do.
Do. .	(236) Mr. Yeo Kyi Han.	Do. .	P. L. .	198·4	16th March 1929.	Do.
Do. .	(237) Messrs. Burma Malaya Mines.	Do. .	P. L. .	51·2	8th December 1929.	Do.
Do. .	(238) Messrs. The Anglo-Burma Tin Co., Ltd.	Do. .	P. L. .	76·8	21st June 1929.	Do.
Do. .	(239) Maung Ba Oh .	Do. .	P. L. .	108·8	18th March 1929.	Do.
Do. .	(240) Messrs. Eu Pola Bros.	Do. .	P. L. .	339·2	27th July 1929.	Do.
Do. .	(241) Mr. Quah Hun Cheong.	Do. .	P. L. .	576·0	12th October 1929.	Do.
Do. .	(242) Maung Ohn Nyun U Dwe.	Do. .	P. L. .	249·6	20th June 1929.	Do.
Do. .	(243) Maung Ohn Nyun.	Do. .	P. L. .	320·0	Do. .	Do.
Do. .	(244) Messrs. Eu Pola Bros.	Do. .	P. L. .	249·6	27th July 1929.	Do.
Do. .	(245) Mr. Rowland Ady.	Do. .	P. L. .	288·0	20th September 1929.	Do.
Do. .	(246) Maung Ohn Nyun.	Do. .	P. L. .	1,376·0	30th September 1929.	Do.
Do. .	(247) Mr. E. Ahmed .	Do. .	P. L. .	454·4	16th July 1929.	Do.
Do. .	(248) U Ba Oh . .	Do. .	P. L. .	537·6	12th October 1929.	Do.
Do. .	(249) Mr. C. Soo Don.	Do. .	P. L. .	320·0	31st July 1929.	Do.
Do. .	(250) Messrs. Crisps & Co.	Do. .	P. L. .	556·8	7th September 1929.	Do.
Do. .	(251) Mr. Teh Lu Pe .	Do. .	P. L. .	1,465·6	12th September 1929.	Do.
Do. .	(252) Mr. Khoo Tun Byan.	Do. .	P. L. .	595·2	7th November 1929	Do.
Do. .	(253) Mr. Quah Cheng Guan.	Do. .	P. L. .	1,478·4	1st November 1929.	Do.
Do. .	(254) Mr. A. J. Robertson.	Do. .	P. L. .	179·2	5th November 1929.	Do.
Do. .	(255) Mr. A. S. Mohamed.	Do. .	P. L. .	294·4	20th November 1929.	Do.

P. L. = *Prospecting License.*

BURMA—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement	Term.
Tavoy .	(256) Mr. Ong Hoe Kyin.	Tin and wolfram .	P. L. .	960·0	20th December 1929.	1 year.
Do. .	(257) Do. .	Do. .	P. L. .	640·0	14th October 1929.	Do.
Do. .	(258) Maung Po Swe .	Do. .	P. L. .	614·4	12th September 1929.	Do.
Do. .	(259) Daw Yai . .	Do. .	P. L. .	512·0	30th November 1929.	Do.
Do. .	(260) Mr. Quah Cheng Guan.	Do. .	P. L. .	358·4	2nd November 1929.	Do.
Do. .	(261) Daw Kyin May.	Do. .	P. L. .	640·0	16th September 1929.	Do.
Do. .	(262) Do. .	Do. .	P. L. .	275·2	30th October 1929.	Do.
Do. .	(263) Messrs. Eu Po Hla Bros.	Do. .	P. L. .	480·0	25th November 1929.	Do.
Do. .	(264) Do. .	Do. .	P. L. .	512·0	16th December 1929.	Do.
Do. .	(265) Maung Ba Oh .	Do. .	P. L. .	595·2	14th November 1929.	Do.
Do. .	(266) Messrs. Newbery and Ward.	Cassiterite . .	M. L. .	761·6	16th July 1929.	30 years.
Do. .	(267) Mr. Ong Hoe Kyin.	Tin and wolfram .	M. L. .	115·2	1st June 1929	Do.
Do. .	(268) Messrs. Consolidated Tin Mines of Burma, Ltd.	Cassiterite and wolfram.	M. L. .	121·6	15th August 1929	Do.
Do. .	(269) Daw Yai . .	Tin and wolfram .	M. L. .	454·4	Do. .	Do.
Do. .	(270) U. Maung Maung	Do. .	M. L. .	360·0 .	1st December 1929.	Do.
Do. .	(271) Mr. Ong Hoe Kyin.	Do. .	M. L. .	864·0	16th November 1929.	Do.
Do. .	(272) Messrs. Consolidated Tin Mines of Burma, Ltd.	All minerals except oil.	M. L. .	512·0	15th August 1929.	Do.
Do. .	(273) Do. .	Tin and allied minerals.	M. L. .	275·2	Do. .	Do.
Do. .	(274) Mr. J. J. A. Page	Cassiterite, gold and wolfram.	M. L. .	345·6	1st December 1929.	20 years.
Do. .	(275) Messrs. Eu Po Hla Bros.	Tin and wolfram .	P. L. . (Renewal).	512·0	26th November 1929.	1 year.
Do. .	(276) Mr. Khoo Sein Shan.	Do.	P. L. . (Renewal).	729·6	25th March 1929.	Do.
Do. .	(277) Mr. Ong Hoe Kyin.	Do. .	P. L. . (Renewal).	115·2	7th May 1929	2 years.

P. L. = *Prospecting License.* M. L. = *Mining Lease.*

BURMA—*concld.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Tavoy .	(278) Messrs. Consolidated Tin Mines, Ltd.	Tin and wolfram .	P. L. . (Renewal).	25·6	24th November 1929.	6 months.
Do. .	(279) Messrs. Anglo-Burma Tin Co.	Do. .	P. L. . (Renewal).	2,284·8	16th August 1929.	1 year.
Do. .	(280) Mr. Kin Shwe .	Do. .	P. L. . (Renewal).	697·6	Do. .	Do.
Do. .	(281) Daw Yai . .	Do. .	P. L. . (Renewal).	569·6	11th September 1929.	Do.
Do. .	(282) Messrs. Tavoy Tin Dredging Corporation, Ltd.	Do. .	P. L. . (Renewal).	448·0	10th September 1929.	Not stated.
Thaton .	(283) Mr. S. Ebrahim.	All minerals except oil.	P. L. .	640·0	30th May 1929.	1 year
Thayetmyo .	(284) Mr. W. R. Smith	Natural petroleum including natural gas.	P. L. .	441·6	2nd September 1929.	2 years.
Do. .	(285) Messrs. Burmah Oil Co., Ltd.	Do. .	P. L. .	1,984·0	16th November 1929.	Do.
Do. .	(286) U Kyauk Lon .	Do. .	P. L. .	102·4	28th August 1929.	Do.
Do. .	(287) U Tun Aung Gyaw.	Do. .	P. L. .	377·6	26th September 1929.	Do.
Do. .	(288) Messrs. Burmah Oil Co., Ltd.	Do. .	P. L. . (Renewal).	1,676·8	8th January 1929.	1 year.
Do. .	(289) Messrs. Indo-Burma Petroleum Co., Ltd.	Do. .	P. L. . (Renewal).	89·6	9th February 1929.	Do.
Do. .	(290) Messrs. Burmah Oil Co., Ltd.	Do. .	P. L. . (Renewal).	224·0	23rd March 1929.	Do.
Do. .	(291) U Tun Aung Gyaw.	Do. .	P. L. . (Renewal).	492·8	12th June 1929.	Do.
Upper Chindwin.	(292) Messrs. Fairweather Richards & Co., Ltd.	Coal . . .	P. L. .	1,868·8	15th August 1929.	Do.
Do. .	(293) Do. .	Do. . . .	P. L. .	704·0	11th March 1929.	Do.
Do. .	(294) Messrs. Indo-Burma Petroleum Co., Ltd.	Natural petroleum	P. L. . (Renewal).	2,560·0	17th March 1929.	Do.

CENTRAL PROVINCES.

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Balaghat .	(295) Mr. Samiulla Khan.	Manganese-ore .	P. L. .	200	29th January 1929.	1 year.
Do. .	(296) Mr. Amritlal P. Trivedi.	Do. .	M. L. .	15	19th February 1929.	9 years.
Do. .	(297) Mr. K. C. Gupta .	Do. .	P. L. .	71	20th March 1929.	1 year.

P. L. = *Prospecting License.* M. L. = *Mining Lease.*

CENTRAL PROVINCES—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Balaghat .	(298) Mr. K. C. Gupta	Manganese-ore .	P. L. .	36	8th February 1929.	1 year.
Do. .	(299) Do. .	Do. .	P. L. .	43	28th March 1929.	Do.
Do. .	(300) Mr. R. P. Mudaliar.	Do. .	P. L. .	200	9th February 1929.	Do.
Do. .	(301) Mr. M. B. Marfatia.	Do. .	P. L. .	48	22nd July 1929.	Do.
Do. .	(302) Mr. Samiulla Khan.	Do. .	P. L. .	200	5th March 1929.	Do.
Do. .	(303) Mr. C. Stanley Harris.	Do. .	M. L. .	1	19th August 1929.	16 years.
Do. .	(304) Mr. Amrit Lal P. Trivedi.	Do. .	M. L. .	20	30th September 1929.	30 years.
Do. .	(305) Mr. K. C. Gupta.	Do. .	P. L. .	141	5th January 1929.	1 year.
Do. .	(306) Mst. Munnabai .	Do. .	M. L. .	94	6th February 1929.	30 years.
Do. .	(307) Mr. Amritlal P. Trivedi.	Do. .	P. L. .	50	25th January 1929.	1 year.
Do. .	(308) Mst. Munnabai .	Do. .	P. L. .	16	24th July 1929.	Do.
Do. .	(309) Mr. Amritlal P. Trivedi.	Do. .	M. L. .	83	19th February 1929.	30 years.
Do. .	(310) Mst. Munnabai .	Do. .	P. L. .	182	16th February 1929.	1 year.
Do. .	(311) Do. .	Do. .	P. L. .	183	12th March 1929.	Do.
Do. .	(312) Mr. M. B. Marfatia	Do. .	P. L. .	34	1st March 1929.	Do.
Do. .	(313) Mst Munnabai .	Do. .	P. L. .	132	24th July 1929.	Do.
Do. .	(314) Mr. M. B. Marfatia	Do. .	M. L. .	32	21st October 1929.	30 years.
Do.	(315) Mst. Munnabai .	Do. .	P. L. .	36	24th July 1929.	1 year.
Do. .	(316) Mr. M. B. Marfatia	Do. .	P. L. .	86	30th October 1929.	Do.
Do. .	(317) Do. .	Do. .	P. L. .	32	21st October 1929.	Do.
Do. .	(318) Do. .	Do. .	P. L. .	11	17th November 1929.	Do.
Do. .	(319) Do. .	Do. .	P. L. .	50	11th November 1929.	Do.
Do. .	(320) Messrs. Oke Brothers.	Do. .	P. L. .	68	21st August 1929.	Do.

P. L. = *Prospecting License.* M. L. = *Mining Lease.*

CENTRAL PROVINCES—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Balaghat .	(321) Mr. M. B. Marfatia	Manganese-ore .	P. L. .	73	21st October 1929	1 year.
Do. .	(322) Messrs. B. P. Byramji & Co.	Do .	M. L. .	8	8th November 1929.	5 years.
Do. .	(323) Do. .	Do. .	M. L. .	11	22nd November 1929.	Do.
Do. .	(324) Do. .	Do. .	M. L. .	4	Do. .	Do.
Do. .	(325) Do. .	Do. .	M. L. .	20	6th November 1929.	Do.
Do. .	(326) Mr. Samiulla Khan.	Do. .	P. L. .	6	21st November 1929.	Do.
Bhandara .	(327) Rao Sahib B. V. Buti.	Do.	P. L. .	6	16th August 1929.	Do.
Do. .	(328) Mr. M. A. Pasha, minor, through guardian Munshi S. Allimuddin.	Do. .	P. L. .	52	19th February 1929.	Do
Do. .	(329) Messrs. Ganpat Sao Dhanpat Sao.	Do. .	P. L. .	4	8th February 1929.	Do.
Do. .	(330) Rai Bahadur Seth Gowardhan Das.	Do.	P. L. .	8	11th November 1929.	Do.
Do. .	(331) Messrs. Namdeo Pandurang.	Do. .	P. L. .	66	5th November 1929.	Do.
Do. .	(332) Messrs. Ganpat Sao Dhanpat Sao.	Bauxite and Oxide of iron.	P. L. .	547	14th October 1929.	Do.
Do. .	(333) Messrs. Yadulal Bhadulal.	Manganese .	M. L. .	5	22nd December 1928.	10 years.
Do. .	(334) Rai Bahadur Seth Govardhan Das.	Do. .	M. L. .	3	6th December 1928.	Do.
Do. .	(335) Do. .	Do.	M. L. .	28	12th December 1928.	Do.
Do. .	(336) Maharaj Jugol Kishore Nath Shah Deo.	Do. .	M. L. .	25	4th June 1929.	30 years.
Do. .	(337) Messrs. B. P. Byramji & Co.	Do. . .	M. L. .	22	23rd February 1929.	5 years.
Bilaspur .	(338) Messrs. Dunlop and Considine Ghordewa Coal Fields Ltd.	Coal and iron .	P. L. .	11,900	9th March 1929.	1 year.
Do. .	(339) Do. .	Coal	P. L. .	3,376	5th November 1928.	Do.
Do. .	(340) Do. .	Do.	P. L. .	4,324	20th November 1928.	Do.
Do. .	(341) Do. .	Do.	P. L. .	12,256	30th June 1928.	Do.

P. L. = Prospecting License. M. L. = Mining Lease.

CENTRAL PROVINCES—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Chhindwara	(342) The Amalgamated Coal Fields Ltd.	Coal	M. L.	60	5th April 1929.	13 years.
Do.	(343) Do.	Do.	M. L.	1	10th October 1929.	20 years.
Do.	(344) Messrs. S. Laxman Rao and B. Narsingh Rao Naidu.	Manganese	P. L.	78	20th February 1929.	1 year.
Do.	(345) Messrs. Balaji Tanhaji.	. . . .	P. L.	81	24th January 1929.	Do.
Do.	(346) Do.	Do.	P. L.	58	Do.	Do.
Do.	(347) Lala Jaganath Prasad and Ramcharanlal.	Limestone	P. L.	4	15th May 1929.	Do.
Do.	(348) Mr. Nritya Gopal Bose.	Manganese	P. L.	16	9th April 1929.	Do.
Damoh	(349) Mr. Dinanath Shrivastava.	Limestone	Q. L.	14	11th April 1929.	10 years.
Do.	(350) Mr. Mahadeo Prasad Shrivastava.	Do.	Q. L.	5	26th September 1929.	Do.
Drug	(351) Lal Indra Shah.	Galena ore	P. L.	12	22nd June 1929.	1 year.
Jubbulpore	(352) Messrs. Macpherson & Co.	Bauxite	M. L.	222	3rd August 1929.	30 years.
Do.	(353) Do.	Do.	M. L.	568	22nd March 1929.	Do.
Do.	(354) Mr. N. Venkat Ramanna.	Do.	M. L.	26	25th December 1928.	Do.
Do.	(355) Do.	Do.	M. L.	50	12th December 1928.	Do.
Do.	(356) Mr. Chakorilal Pathak.	Do.	M. L.	1	23rd May 1929.	10 years.
Nagpur	(357) Messrs. Namdeo Pandurang Dalal.	Manganese	P. L.	128	16th April 1929.	1 year.
Do.	(358) Do.	Do.	P. L.	46	Do.	Do.
Do.	(359) Messrs. Ganpat Sao Dhanpat Sao.	Do.	P. L	98	31st January 1929.	Do.
Do.	(360) Messrs. N. D. Zal Brothers.	Do.	P. L.	6	14th August 1929.	Do.
Do.	(361) Mr. S. Vinayakrao	Do.	M. L.	10	8th January 1929.	10 years.
Do.	(362) The Central Provinces Tiles and Brick manufacturing Co.	Clay	Q. L.	4	13th May 1929.	5 years.
Do.	(363) Do.	Do.	Q. L.			
Do.	(364) Mr. Balaram Ramchandra.	Do.	Q. L.	18	24th April 1929.	10 years.

P. L. = *Prospecting Licence.* M. L. = *Mining Lease.* Q. L. = *Quarry Lease.*

CENTRAL PROVINCES—*concld.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Nagpur .	(365) Mr. Budhulal Balaram.	Clay . . .	Q. L. .	11	5th April 1929.	10 years.
Do. .	(366) Mr Yenku Upashya.	Do. . . .	Q. L. .	1	21st January 1929.	Do.
Do. .	(367) Maharaj Kumar Jugal Kishore Nath Shah Deo.	Manganese . .	M. L .	164	22nd January 1929.	30 years.
Do. .	(368) Mr. Wadgoo Mistry.	Clay . . .	Q. L.	2	21st August 1929.	5 years.
Do. .	(369) Rao Sahab B. V. Buti.	Do. . . .	Q. L. .	3	22nd April 1929.	2 years.
Do. .	(370) Mr. Bhawanji Naranji.	Manganese . .	M. L. .	5	22nd March 1929.	30 years.
Do. .	(371) Mr. Shamji Naranji.	Do. . .	M. L. .	7	28th February 1929.	15 years.
Do. .	(372) Messrs. C. Harmosjee N. Rustomjee.	Do. . .	M. L. .	10	22nd February 1929.	5 years.
Do. .	(373) Do. .	Do. . .	M. L. .	46	Do. .	10 years.
Do. .	(374) Mr. Chhanoo Kumbhar.	Clay . . .	Q. L. .	2	19th September 1929.	Do.
Do. .	(375) Mr. Ganpat Rao Laxman Rao.	Manganese . .	M. L. .	14	20th March 1929.	30 years.
Do. .	(376) Messrs. Nathu and Narayan.	Clay . . .	Q. L. .	2	11th July 1929.	10 years.
Do. .	(377) Mr. Khuman Puran.	Do. . . .	Q. L. .	3	8th July 1929	Do.
Do. .	(378) Mr. Goswami Maheshpuri.	Manganese . .	M. L. .	26	8th February 1929.	Do.
Do. .	(379) Mr. S. Aminuddin	Limestone . .	P. L. .	24	5th November 1929.	1 year.
Do. .	(380) K. C. Gupta .	Manganese . .	P. L. .	81	1st August 1929.	Do.
Do. .	(381) Do. .	Do. . .	P. L. .	28	14th October 1929	Do.
Do. .	(382) Mr. Ramlal Ramchand.	Clay . . .	Q. L. .	1	2nd March 1929.	10 years.
Do. .	(383) Messrs. Tularam. Brijalal and Dhekal.	Do.	Q. L. .	3	17th October 1929.	Do.
Do. .	(384) Mr. Ramlal Ramchand.	Do. . .	Q. L. .	1	13th August 1929.	5 years.
Do. .	(385) Mr. Ardeshir Framji.	Limestone . .	Q. L. .	4	5th December 1929.	Do.
[N]arsinghpur	(386) Mr. I. P. Dutta .	Soapstone . .	P. L. .	20	8th January 1929.	1 year.
[Se]oni . .	(387) Rai Sahib Ajodhya Prosad Bhargava.	Manganese . .	P. L. .	367	30th January 1929.	Do.

P. L. = *Prospecting Licence.* M. L. = *Mining Lease.* Q. L. = *Quarry Lease.*

MADRAS.

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Anantapur .	(388) Moka Pedda Narasayya.	China cla . .	M. L. .	14·54	26th September 1928.	5 years.
Do .	(389) M. Rajagopal Nayudu.	Mica . . .	P. L. .	30·75	13th December 1928.	1 year.
Do. .	(390) Kopparapu Venkatasubbayya.	Barytes . .	P. L. (Renewal) .	22·25	1st September 1928.	Do.
Bellary .	(391) E. H. Rushton .	Manganese-ore .	P. L. .	729·22	19th June 1929.	Do.
Do. .	(392) A. Pichayya Nayudu.	Do. .	P. L. .	460·01	22nd July 1929.	Do.
Do. :	(393) Do. .	Do. .	P. L. .	245·05	Do. .	Do.
Cuddapah .	(394) Sitaramachar .	Asbestos . .	P. L. .	1,790·74	1st February 1929.	Do.
Do. .	(395) Kopparapu Venkatasubbayya.	Barytes . .	P. L. .	62·08	Do. .	Do.
Do. .	(396) Isanaki Ramasubba Reddi.	Manganese-ore .	P. L. .	626·80	22nd August 1929.	Do.
Do. .	(397) H. A. Golwynne.	Asbestos . .	P. L. .	1,695·85	2nd June 1929.	Do.
Do. .	(398) Do. .	Do. . .	P. L. .	802·32	Do. .	Do.
Do. .	(399) Mysore Asbestos Mines, Ltd.	Do. . .	P. L. .	538·93	20th July 1929.	Do.
Do. .	(400) Do. .	Do. . .	P. L. .	189·36	Do. .	Do.
Do. .	(401) H. A. Golwynne	Do. . .	P. L. (Renewal). .	24·20	17th September 1929.	Do.
Do. .	(402) Thomas Tiffin .	Barytes . .	P. L. .	39·65	7th December 1929.	Do.
East Godavari	(403) P. Venkayya .	Mica . . .	P. L. .	21·10	23rd August 1929.	Do.
Kurnool .	(404) S. P. Ranga Rao	Do. . . .	P. L. .	4·00	29th June 1929.	Do.
Do. .	(405) Do. .	Do. . . .	P. L. .	18·00	25th July 1929.	Do.
Do. .	(406) Do. .	Do. . . .	P. L. .	0·35	9th May 1929	Do.
Do. .	(407) Do. .	Do. . . .	P. L. .	8·00	Do. .	Do.
Do. .	(408) Do. .	Do. . . .	P. L. .	8·00	18th December 1929.	Do.
Do. .	(409) Do. .	Do. . . .	P. L. .	36·98	4th December 1929.	Do.
Do. .	(410) B. P. Sesha Reddi	Do. . . .	P. L .	12·00	14th May 1929.	Do.
Do. .	(411) Do. .	Do. . . .	P. L. .	4·00	Do. .	Do.
Do. .	(412) Do. .	Do. . . .	P. L. .	10·82	4th February 1929.	Dc.

P. L. = *Prospecting License.* M. L. = *Mining Lease.*

MADRAS—*contd.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Kurnool .	(413) B. P. Sesha Reddi.	Mica . .	P. L. .	1·62	11th March 1929.	1 year.
Do. .	(414) Do. .	Do. . . .	P. L. .	2·40	17th May 1929.	Do.
Do. .	(415) Ashruff Hussain Khan.	Do. . . .	P. L. .	31·00	18th May 1929.	Do.
Do. .	(416) Do. .	Do. . . .	P. L. .	4·12	7th November 1929.	Do.
Do. .	(417) Do. .	Do. . . .	P. L. .	20·00	25th July 1929.	Do.
Do. .	(418) Do. .	Do. . . .	P. L. .	3·20	1st August 1929.	Do.
Do. .	(419) V. V. Subbayya Pantulu.	Do. . . .	P. L. .	6·00	10th April 1929.	Do.
Do. .	(420) Do. .	Do. . . .	P. L. .	4·00	10th February 1929.	Do.
Do. .	(421) Do. .	Do. . . .	P. L. .	3·50	Do. .	Do.
Do. .	(422) Do. .	Do. . . .	P. L. .	4·00	3rd December 1929.	Do.
Do. .	(423) Do. .	Do. . . .	P. L. .	16·00	Do. .	Do.
Do. .	(424) Khan Bahadur Waljee Laljee.	Diamonds and copper	P. L. .	8·65	25th September 1929.	Do.
Do. .	(425) Ashruff Hussain Khan Mandozie. .	Barytes . .	P. L. .	7·00	1st December 1929.	Do.
Do. .	(426) S. Jayarama Reddi.	Do. . .	P. L. .	31·75	20th November 1929.	Do.
Nellore .	(427) A. Rama Nayadu	Mica .	P. L. .	1·98	12th March 1929.	Do.
Do. .	(428) T. C. Dandayudham Pillai.	Do. . .	M. L. .	0·99	28th September 1928.	Till 25th June 1956.
Do. .	(429) M. Subbarayudu	Do. . . .	M. L. .	2·38	15th May 1929.	30 years.
Do. .	(430) G. C. Subba Reddi	Do. . . .	M. L. .	12·04	25th September 1929.	Do.
Do. .	(431) Kolli V. Subba Reddi.	Do. . . .	P. L. .	22·30	12th April 1929.	1 year.
Do. .	(432) C. V. Subba Reddi.	Do. . . .	P. L. .	4·47	7th April 1929.	30 years.
Do. .	(433) Sayed Khajamea	Do. . . .	M. L. .	9·89	11th January 1929.	Do.
Do. .	(434) Do. .	Do. . . .	M. L. .	60·67	Do. .	Do.
Do. .	(435) K. Seshayya Chetti and another.	Do. . . .	M. L. .	6·59	12th February 1929.	Till 30th September 1944.
Do. .	(436) P. Papi Reddi .	Do. . . .	P. L. .	21·13	17th July 1929.	1 year.

P. L. = Prospecting License. M. L. = Mining Lease.

MADRAS—*concld.*

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Nellore .	(437) P. Papi Reddi .	Mica	P. L. .	35·24	17th July 1929	1 year.
Do. .	(438) G. Chanchayya .	Do. . . .	M. L. .	1·45	5th March 1929.	30 years.
Do. .	(439) M. Rama Rao .	Do. . . .	M. L. .	6·05	22nd August 1929.	Do.
Do. .	(440) V. Venkatasubbayya.	Do. . . .	P. L. .	5·01	Do. .	1 year.
Do. .	(441) P. Venkayya .	Do. . . .	P. L. .	39·72	9th June 1929.	Do.
Do. .	(442) Do. .	Do. . . .	P. L. .	73·10	12th April 1929.	Do.
Do. .	(443) T. Vasu . .	Do. . . .	P. L. .	28·87	13th July 1929.	Do.
Do. .	(444) V. Venkatasubbayya.	Do. . . .	P. L. .	26·28	10th July 1929.	Do.
Do .	(445) Rao Sahib P. Veera Reddi.	Do. . . .	M. L. .	4·42	12th October 1929.	30 years.
Do. .	(446) S. V. Subba Reddi	Do. . . .	P. L. .	28·60	9th October 1929.	1 year.
North Arcot.	(447) H. A. Golwynne	Pyrites .	P. L. .	1,060·00	5th November 1928.	Do.
Do. .	(448) Do. .	Do. . . .	P. L. .	1,280·00	2nd March 1929.	Do.
Do. .	(449) Do. .	Do. . . .	P. L. .	424·00	25th May 1929.	Do.
Trichinopoly	(450) C. Middleton .	Phosphatic nodules and gypsum.	M. L .	430·22	1st July 1929.	5 years.

NORTH-WEST FRONTIER PROVINCE.

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Dera Ismail Khan.	(451) The Indo-Burma Petroleum Co., Ltd.	Natural petroleum (including natural gas).	P. L. .	1,321·6	10th March 1929.	1 year.
Do. .	(452) Do. .	Do. .	P. L.	2,995·2	10th September 1929.	Do.
Do. .	(453) Do. .	Do. .	P. L. . (Renewal).	10,880·0	2nd February 1929.	Do.
Do. .	(454) Do. .	Do. .	P. L. . (Renewal).	3,040·0	4th August 1929.	Do.
Kohat .	(455) Burmah Oil Co., Ltd.	Mineral oil . .	E. L. .	Shinghar hills and Thall in Teri *tahsil* and Panolia and Chorlaki in Kohat *tahsil*.	25th March 1929.	Do.

P. L. = *Prospecting License.* M. L. = *Mining Lease.* E. L. = *Exploring License.*

PUNJAB.

District.	Grantee.	Mineral.	Nature of grant.	Area in acres.	Date of commencement.	Term.
Jhelum .	(456) L. Ram Lal .	Coal . . .	P. L. .	96	18th February 1929.	1 year.
Do. .	(457) L. Sant Ram .	Do. . . .	M. L. .	94	1st March 1928.	10 years.

P. L. = *Prospecting License.* M. L. = *Mining Lease.*

SUMMARY.

Province	Exploring License.	Prospecting License.	Mining Lease.	Quarry Lease.	Total of each Province.
Ajmer-Merwara . .	..	17	1	..	18
Assam . . .	..	20	..	..	20
Baluchistan . . .	..	..	1	..	1
Bengal . . .	..	1	..	..	1
Bihar and Orissa . .	..	12	19	..	31
Bombay . . .	..	4	..	..	4
Burma. . . .	..	180	39	..	219
Central Provinces . .	..	47	30	16	93
Madras . . .	..	52	11	..	63
N.-W. F. Province. .	1	4	..	..	5
Punjab . . .	..	1	1	..	2
Total of each kind and grand total, 1929.	1	338	102	16	457
TOTAL FOR 1928 .	..	396	100	1	497

Classification of Licenses and Leases.

TABLE 43.—*Prospecting Licenses and Mining Lease granted in Ajmer-Merwara during the year 1929.*

Districts.	1929. No.	1929. Area in acres.	1929. Mineral.
		Prospecting Licenses.	
Ajmer	11	31·54	Mica.
Do.	1	20·00	Graphite.
Do.	1	2·00	Mica, beryl and aquamarine.
Beawar	4	12·38	Mica.
Total	17	..	
		Mining Lease.	
Beawar	1	3·8	Mica.

TABLE 44.—*Prospecting Licenses granted in Assam during the year 1929.*

District.	1929. No.	1929. Area in acres.	1929. Mineral.
Cachar	2	3,148·8	Mineral oil.
Khasi and Jaintia Hills	2	1,280·8	Sillimanite.
Lakhimpur	8	24,828·8	Mineral oil.
Do.	1	3,616·0	Coal.
Manipur	1	1,140·0	Copper.
Sadiya Frontier Tract	1	2,240·0	Oil.
Sibsagar	2	10,144·0	Mineral oil.
Sylhet	3	15,603·2	Do.
Total	20	..	

TABLE 45.—*Mining Lease granted in Baluchistan during the year 1929.*

DISTRICT.	1929.		
	No.	Area in acres.	Mineral.
Sibi	1	80	Coal and coal dust.

TABLE 46.—*Prospecting License granted in Bengal during the year 1929.*

DISTRICT.	1929.		
	No.	Area in acres.	Mineral.
Chittagong	1	4,000	Natural petroleum.

TABLE 47.—*Prospecting Licenses and Mining Leases granted in Bihar and Orissa during the year 1929.*

DISTRICT.	1929.		
	No.	Area in acres.	Mineral.
PROSPECTING LICENSES.			
Angul	1	640·00	Red ochre.
Singhbhum	5	5,368·45	Iron-ore and manganese.
Do.	2	2,168·32	Chromite.
Do.	2	533·20	Manganese.
Do.	1	1,491·20	Iron-ore.
Do.	1	548·00	All minerals except iron-ore and mica.
TOTAL .	12	..	
MINING LEASES.			
Santal Parganas	8	26·32	Coal.
Singhbhum	3	1,083·20	Chromite.
Do.	2	243·75	Manganese.
Do.	2	264·48	Iron-ore.
Do.	4	2,350·97	Iron-ore and manganese.
TOTAL .	19	..	

TABLE 48.—*Prospecting Licenses granted in the Bombay Presidency during the year 1929.*

DISTRICT.	1929.		
	No.	Area in acres.	Mineral.
Belgaum	1	60·0	Bauxite.
Kanara	2	2,350·4	Manganese.
Ratnagiri	1	1,280·0	Chromite.
TOTAL .	4	..	

TABLE 49.—*Prospecting Licenses and Mining Leases granted in Burma during the year 1929.*

DISTRICT.	1929.		
	No.	Area in acres.	Mineral.
	PROSPECTING LICENSES.		
Akyab	7	22,419·2	Natural petroleum including natural gas.
Amherst	5	7,195·0	All minerals except oil.
Lower Chindwin . . .	9	47,993·6	Natural petroleum including natural gas.
Magwe	5	9,280·0	Ditto.
Meiktila	1	1,318·4	All minerals other than natural petroleum.
Do.	1	358·4	All minerals except precious stone.
Do.	1	473·6	All minerals other than mineral oil.
Mergui	11	3,612·0	Tin and allied minerals except mineral oil.
Do.	25	9,776·6	Tin-ore.
Do.	3	1,113·6	Tin-stone, and allied minerals.
Do.	10	6,112·0	Tin and other allied minerals.
Do.	5	2,675·2	All minerals except oil.
Do.	3	889·6	All minerals other than petroleum and precious stones.
Do.	1	2,547·2	Tin and gold.
Do.	2	2,278·4	Tin, wolfram and other allied metals.

TABLE 49.—*Prospecting Licenses and Mining Leases granted in Burma during the year 1929*—concld.

DISTRICT.	1929. No.	1929. Area in acres.	1929. Mineral.
	PROSPECTING LICENSES—*contd.*		
Mergui	1	396·8	Cassiterite, wolfram and allied minerals.
Minbu	1	2,560·0	Coal.
Myingyan	1	1,280·0	Mineral oil.
Myitkyina	4	6,720·0	All minerals except oil.
Northern Shan States	2	2,240·0	Lead and silver ore.
Pakokku	6	4,499·2	Natural petroleum.
Salween	1	2,560·0	All minerals except mineral oil.
Shwebo	2	10,553·6	Natural petroleum including natural gas.
Southern Shan States	7	18,016·0	Silver and lead.
Do.	1	530·4	Slag.
Do.	1	832·0	All minerals except oil.
Do.	1	576·0	Wolfram.
Tavoy	51	28,345·6	Tin and wolfram.
Thaton	1	640·0	All minerals except oil.
Thayetmyo	8	5,588·8	Natural petroleum including natural gas.
Upper Chindwin	2	2,572·8	Coal.
Do.	1	2,560·0	Natural petroleum.
TOTAL	180	..	
	MINING LEASES.		
Mergui	4	966·4	Tin-ore.
Do.	18	5,472·0	Tin and allied minerals.
Do.	1	32·0	Tin and allied minerals except mineral oil.
Do.	1	390·0	Tin and wolfram.
Do.	1	857·6	Cassiterite.
Do.	1	832·0	All minerals except natural petroleum and natural gas.
Pakokku	2	1,280·0	Natural petroleum.
Southern Shan States	1	243·2	Slag.
Tavoy	5	2,433·6	Tin and wolfram.
Do.	1	761·6	Cassiterite.
Do.	1	121·6	Cassiterite and wolfram.
Do.	1	512·0	All minerals except oil.
Do.	1	275·2	Tin and allied minerals.
Do.	1	345·6	Cassiterite, gold and wolfram.
TOTAL	39		

TABLE 50.—*Prospecting Licenses and Mining and Quarry Leases granted in the Central Provinces during the year 1929.*

District.	1929. No.	1929. Area in acres.	1929. Mineral.
PROSPECTING LICENSES.			
Balaghat	22	1,893	Manganese.
Bhandara	5	136	Do.
Do.	1	547	Bauxite and oxide of iron.
Bilaspur	1	11,900	Coal and iron.
Do.	3	19,956	Coal.
Chhindwara	4	233	Manganese.
Do.	1	4	Limestone.
Drug	1	12	Galena.
Nagpur	6	387	Manganese.
Do.	1	24	Limestone.
Narsinghpur	1	20	Soapstone.
Seoni	1	367	Manganese.
TOTAL	47	..	
MINING LEASES.			
Balaghat	10	288	Manganese.
Bhandara	5	78	Do.
Chhindwara	2	61	Coal and iron.
Jubbulpore	5	867	Bauxite.
Nagpur	8	282	Manganese.
TOTAL	30	..	
QUARRY LEASES.			
Damoh	2	19	Limestone.
Nagpur	13	51	Clay.
Do.	1	4	Limestone.
TOTAL	16	..	

Table 51.—*Prospecting Licenses and Mining Leases granted in Madras during the year 1929.*

District.	1929. No.	1929. Area in acres.	1929. Mineral.
	Prospecting Licenses.		
Anantapur	1	30·75	Mica.
Do.	1	22·25	Barytes.
Bellary	3	1,434·28	Manganese.
Cuddapah	6	5,041·40	Asbestos.
Do.	2	101·73	Barytes.
Do.	1	626·80	Manganese.
East Godavari	1	21·10	Mica.
Kurnool	20	197·49	Do.
Do.	1	8·65	Diamonds and copper.
Do.	2	38·75	Barytes.
Nellore	11	286·70	Mica.
North Arcot	3	2,764·00	Pyrites.
Total	52	..	
	Mining Leases.		
Anantapur	1	14·54	China clay.
Nellore	9	104·48	Mica.
Trichinopoly	1	430·22	Phosphatic nodules and gypsum.
Total	11	..	

Table 52.—*Prospecting and Exploring Licenses granted in the N.-W. F. Province during the year 1929.*

District.	1929. No.	1929. Area in acres.	1929. Mineral.
	Prospecting Licenses.		
Dera Ismail Khan	4	18,236·8	Natural petroleum including natural gas.
	Exploring Licenses.		
Dera Ismail Khan	1	Shinghar hills and Thall in Teri *tahsil* and Panolia and Chorlaki in Kohat *tahsil*.	Natural petroleum including natural gas.

TABLE 53.—*Prospecting License and Mining Lease granted in the Punjab during the year 1929.*

District.	1929.		
	No.	Area in acres.	Mineral.
	PROSPECTING LICENSE.		
Jhelum	1	96	Coal.
	MINING LEASE.		
Jhelum	1	94	Coal.

ON THE SPECIFIC GRAVITY AND PROXIMATE COMPOSITION OF SOME INDIAN DURAINS. BY L. LEIGH FERMOR, O.B.E., D.SC., A.R.S.M., M.I.M.M., F.G.S., *Officiating Director, Geological Survey of India.* (With Plate 9.)

CONTENTS.

I.—INTRODUCTION.

IN a paper entitled 'On the Relationship between the Specific Gravity and Ash Contents of the Coals of Korea and Bokaro : Coals as Colloid Systems'[1], the results are given of a study, by means of proximate analyses and specific gravity determinations, of two series of coals each ranging from vitrain at the low-ash end of the series to low-grade coals, and in one case (Bokaro) also to carbonaceous shales, at the high-ash end. The longer and more complete series of specimens—22 in number, represented by 30 analyses—from the Bokaro coalfield, range in specific gravity from 1·28 to 2·58, and in ash contents from 2·31 per cent. to 87·41 per cent. A study of the data obtained shows that these coals and shales can be sorted into two series.

Of these one series is a vitrain-durain series ranging from bright, through silky, to dull coals, with ash contents ranging in these specimens from 2 to 39 per cent., and with a linear relationship between ash contents and specific gravity, the rule being

$$a = 100\,(g-k),$$

in which a is the ash contents, g the corresponding specific gravity, and k the specific gravity of pure ash-free coal or vitrain. This linear relationship is interpreted as proving that this vitrain-durain

[1] *Rec. Geol. Surv. Ind.*, LX, pp. 313-357, (1928).

series can be treated as a series of suspensoid colloid systems in which the vitrain acts as the dispersion medium and the ash contents as the disperse phase (suspensoid), with the vegetable detritus contained in the durain as a second disperse phase (coarse suspension).

The other series is a vitrain-carbonaceous shale series ranging from shaly coals to coaly and carbonaceous shales, with ash contents ranging from 27 to 89 per cent. In this series the relationship between ash contents and specific gravity is not linear, and the data are interpreted as proving that the carbonaceous substances in this second series are the products of interlamination of vitrain and carbonaceous shale and that the carbonaceous shales themselves are mechanical mixtures of inorganic and organic matter (coarse suspensions), and not colloid systems.

The practical value of the above work is that by using the equation

$$a = 100\,(g - k)$$

one can determine the ash contents a of a specimen in the field very simply and with reasonable accuracy by taking the specific gravity g with a Walker's balance, provided one already knows the value of k, the specific gravity of ash-free vitrain for that field. This is previously determined by picking out from the bright bands of vitrain material as pure as possible and making a determination of the specific gravity and also a proximate analysis. The ash contents will probably prove to be only from about ½ to 4 per cent. The value of k is found by subtracting from the value of the specific gravity as found 0·01 for each 1 per cent. of ash. The value of k for Bokaro determined in this way proved to be 1·26.

As a preliminary investigation showed that the value of k varies from field to field, it became necessary to determine this constant for as many fields as possible, and this is done in a second paper 'On the Specific Gravity and Proximate Composition of some Indian Vitrains'.[2] In this paper data are given for some 20 coalfields and localities ranging from Barakar to Siwalik in age, and it is found that on the whole the value of k increases with the moisture contents, the lowest value of k being 1·230 with moisture contents of 1·65 per cent. (Lairangao, Assam), and the highest value 1·382 with moisture contents of 15·10 per cent. (Siwalik, Kashmir),

[2] *Rec. Geol. Surv. Ind.*, LXII, pp. 189-228, (1929).

the actual lowest and highest moistures being 0·85 per cent. (k= 1·258, Giridih) and 15·47 per cent. (k=1·352, Rajmahal).

In the first paper it was shown that the ash-content acts as the disperse phase in the vitrain as dispersion medium : in this second paper it is shown that the vitrain itself is probably a colloid system analogous to a dry gel (in this case moisture-free vitrain) that has imbibed water (the moisture).

Other interesting points concerning the behaviour and relationships of vitrains are brought out in the same paper, but it is unnecessary to refer to these now.

Having studied first a vitrain-durain series from one field (Bokaro) and secondly vitrains from as many fields as possible, it seems desirable to complete the investigation by a study of selected specimens of durain from several coalfields. This is undertaken in the present paper. A series of specimens of dull coals—which happen all to be of Gondwana age—has been selected by me, and as before, the actual piece on which the specific gravity has been determined by use of the Walker's balance has been utilised for the proximate analysis. As before, the analytical work has been carried out by Mahadeo Ram in the Laboratory of the Geological Survey of India.

II.—TABLES OF SPECIFIC GRAVITY AND PROXIMATE ANALYSIS.

The data obtained have been divided into two groups according to whether the specimens analysed proved strongly caking on the one hand (Table 1), or non-caking or but slightly caking on the other hand (Table 2). This subdivision also agrees with classification on a moisture basis, for the caking coals in Table 1 range in moisture from 0·58 to 1·61 per cent. on an ash-free basis, whilst the non-caking or but feebly caking coals and carbonaceous shales in Table 2 range in moisture from 2·79 to 8·83 per cent.

In these tables the proximate analysis and specific gravity (g) as returned by the analyst are given in columns 6 to 10. These are followed in columns 11 to 14 by data reduced to an ash-free basis. The specific gravity (g_1) on an ash-free basis is obtained by deducting 0·01 for each 1 per cent. of ash present from the specific gravity (g) as actually determined, as follows from the linear equation already given (page 358). Thus :—

$$g_1 = g - \frac{a}{100}.$$

If these durains consisted only of mineral matter in colloidal suspension as the disperse phase in vitrain as the dispersion medium, then the values of g_1 thus deduced should be the same as the values of k, the specific gravity of ash-free vitrain from the same fields. The difference in each case of $g_1 - k$ from zero is a measure of the deviation of the particular coal from the linear law as explained on page 324 *et seq.* of the first paper, and is shown in column 19 of each table. This deviation is a measure of the sum of three factors, namely, experimental error, the presence of vegetable debris (*e.g.* spores) in suspension, and abnormal composition of the mineral matter.

In column 18 is given the description of the specimen. The names there given have been chosen after comparing the specimens with the two type series from the Korea and Bokaro coalfields discussed in the first paper and listed in tables 1 and 2 on pp. 319 and 323 thereof.

All those described as *silky coal* or as *greasy-lustred coal* or *shale-coal* may be regarded as true durains, the silky coals containing a higher proportion of vitrain, and a lower proportion of ash than the greasy-lustred coals. My original description of these types under the name of *dull coal*, before the terms durain and vitrain had been proposed, occurs in my paper 'On the Geology and Coal Resources of Korea State, Central Provinces', *Mem. Geol. Surv. Ind.*, XLI, p. 181, (1914), and may usefully be quoted here :—

'The *dull coal* can only be so called by comparison with the bright coal. It really has a distinct lustre varying from greasy to silky, and often shows as low a specific gravity as bright coal. Thus a dull greasy-looking shaly coal from Kachhan Kundi Nala has a specific gravity as low as 1·36. As will be seen from the analysis in table 1, such coal is of high quality. Specimens of banded bright and dull coal from seams 1 and 2, Karar Khoh (Kaoria Nala), show G=1·35 and 1·38 respectively.

The dull coal tends to possess a shaly structure and seems to gradate (*see* analysis of K. 3, table 1, for an intermediate stage) into a stony coal-shale or shale-coal of very distinctive appearance. This is heavy (G = 1·64) with a grey-black colour, almost bluish in the sun, a greasy lustre and a conchoidal fracture; the general appearance is that shown by some varieties of psilomelane, except for the fact that this shale-coal is commonly thickly besprinkled with fragments of carbonised vegetable matter, and that it often shows small stringers and veinlets of bright coal. It tends to fracture into slabby pieces, but the shaly structure is not well developed. I refer to it, however, as shale-coal in this report. Its composition is well shown by the analysis of D. 154 in table 1.

In addition, any of the varieties of coal may show films of "mineral charcoal" or "mother-of-coal".'

TABLE 1.—*Analyses and specific gravities of picked specimens*

Coalfield.	Locality or seam.	Field No.	Register No.	Date of analysis.	Data as determined. Moisture. M.	Volatile matter. V.	Fixed carbon. C.	Ash. A.	Specific gravity. G.
					Per cent.	Per cent.	Per cent.	Per cent.	
Bokaro . .	Seam 15, Sawang .	F. 175	23·966	4-12-26	0·98	22·05	37·60	39·37	1·65
Jharia . .	Seam 17, Bhagaband	Jh. 12	N. 243	8-4-30	0·80	19·92	38·49	40·79	1·683
Giridih . .	Karharbari seam .	..	N. 332	Do.	0·46	22·56	56·75	20·23	1·484
Jharia . .	Seam 8, New Jinagora	..	N. 237	Do.	0·54	15·90	43·52	40·04	1·682
Raniganj .	....	Rb. 6	N. 218	Do.	0·85	21·75	52·72	24·68	1·538
Jharia . .	Seam 9, S. S. W. of Parbad.	..	N. 253	Do.	0·36	18·91	38·72	42·01	1·731
Wankie . .	New Colliery . .	Af. 151	..	Do.	1·00	21·20	63·98	13·82	1·403

TABLE 2.—*Analyses and specific gravity of picked specimens of durain*

Coalfield.	Locality or seam.	Field No.	Register No.	Date of analysis.	Data as determined. Moisture. M.	Volatile matter. V.	Fixed carbon. C.	Ash. A.	Specific gravity. G.
					Per cent.	Per cent.	Per cent.	Per cent.	
Kurasia . .	Karar Khoh . .	K. 2	27·432	18-1-13	3·80	22·28	38·96	34·96	1·61
Talcher . .	Villiers' property .	..	N. 330	8-4-30	5·90	34·42	52·83	6·85	1·373
S. Karanpura .	Stone band, Argada Colliery.	Kp. 6	N. 193	5-1-28	2·00	23·90	25·70	48·40	1·789
Kurasia . .	Karar Khoh . .	D. 154	26·639	4-5-13	4·10	19·10	43·52	33·28	1·64
Raniganj . .	Bowla seam, Sunkerpur Colliery.	Rr. 22	N. 329	8-4-30	4·27	28·81	33·13	33·79	1·645
Jainti . .	Top seam, Banskupi Colliery.	..	N. 329	Do.	4·16	26·00	52·54	17·30	1·483
S. Karanpura .	Stone band, Argada Colliery.	Kp. 6	N. 193	Do.	2·02	22·68	31·68	43·62	1·749
Umaria . .	No. 8 p't . . .	..	N. 327	Do.	5·99	21·36	40·48	32·17	1·680
S. Karanpura .	Lower section, Argada.	Kp. 8	N. 195	5-1-28	1·77	19·75	20·92	57·56	1·958
Do. .	Do. .	Kp. 8	N. 195	8-4-30	1·42	18·53	24·99	55·06	1·940
Do. .	Upper section, Argada.	Kp. 5	N. 192	Do.	1·88	31·62	33·78	32·72	1·758
Do. .	Do. .	Kp. 5	N. 192	5-1-28	2·08	36·09	28·89	33·03	1·764

of durain of Barakar age from 5 coalfields : caking coals.

Data on ash-free basis.				Fuel-ratio. $\frac{C}{V}$	Calour of ash.	Caking properties.	Description of specimen.	Deviations taken from Table 5.
Specific gravity. G_1	Moisture. M_1	Volatile matter. V_1	Fixed carbon. C_1					
	Per cent.	Per cent.	Per cent.					
1·256	1·61	36·37	62·02	1·70	Greyish white .	Cakes strongly	Dull greasy-lustred coal.	0
1·275	1·35	33·65	65·00	1·93	Light cream .	Do. .	Dull silky coal with some vitrain.	0
1·282	0·58	28·28	71·14	2·51	Pinkish buff .	Do. .	Silky coal with vitrain laminæ.	+2
1·282	0·90	26·52	72·58	2·74	White . .	Do. .	Dull silky coal with some vitrain.	+1
1·291	1·13	28·87	70·00	2·42	Do. . .	Do. .	Dull greasy-lustred coal with vitrain.	+5
1·311	0·62	32·61	66·77	2·04	Light cream .	Do. .	Dull silky coal with vitrain.	+4
1·325	1·16	24·60	74·24	3·02	White . .	Do. .	Silky coal . .	+5

of Barakar and Raniganj age from 6 coalfields : non-caking coals.

Data on ash-free basis.				Fuel-ratio. $\frac{C}{V}$	Colour of ash.	Caking properties.	Description of specimen.	Deviations taken from Table 6.
Specific gravity. G_1	Moisture. M_1	Volatile matter. V_1	Fixed carbon. C_1					
	Per cent.	Per cent.	Per cent.					
1·260	5·84	34·26	59·90	1·75	Very light brown.	Does not cake	Greasy-lustred shale-coal.	—4
1·305	6·33	36·95	56·72	1·53	Mars brown .	Cakes, but very poorly.	Dull coal rich in fusain.	—2
1·305	3·87	46·32	49·81	1·08	Light cream .	Do. .	Dull greasy-lustred coal approaching shale.	+2
1·307	6·14	28·63	65·23	2·31	Brown . .	Does not cake .	Greasy-lustred shale-coal.	+1
1·307	6·45	43·52	50·04	1·15	Light cream .	Do. .	Dull greasy-lustred shale-coal.	+3
1·310	5·03	31·44	63·53	2·02	Cream-buff .	Do. .	Greasy lustred shale-coal with fusain.	+4
1·318	3·58	40·23	56·19	1·39	Light cream .	Cakes, but very poorly.	Dull greasy-lustred coal approaching shale.	+2
1·358	8·83	31·49	59·68	1·39	Do. .	Does not cake .	Greasy-lustred shale-coal.	+3
1·377	4·18	46·53	49·29	1·06	White . .	Does not cake, but sinters slightly.	Carbonaceous shale	+9
1·389	3·16	41·23	55·11	1·35	Do. . .	Does not cake .	Do. .	+10
1·431	2·79	47·00	50·21	1·07	Isabella colour	Does not cake, but sinters slightly.	Rather hackly granular coal with some vitrain.	+14
1·434	3·10	53·76	43·14	0·80	Light heliotrope purple.	Cakes but not strongly.	Do. .	+14½

The analysis of D. 154 referred to in the above quotation is included in Table 2 of this present paper. The dull coals and shale-coals, both silky and greasy-lustred, of the above quotation are what are now termed durain; the 'carbonised vegetable matter', 'mineral charcoal' and 'mother-of-coal' correspond to fusain; and the bright coal to vitrain.

All the specimens listed in Table 1 are true durains (with often some visible vitrain), as also all the specimens listed in Table 2 (with sometimes visible fusain and vitrain), except the last two, from Argada in the South Karanpura coalfield, each represented by two analyses. Specimen No. N. 195 is a carbonaceous shale by appearance and the high deviations (+9 and +10) given in column 19 show that N. 195 is a mechanical mixture and not a suspensoid colloid system. Specimen N. 192 has a somewhat hackly fracture due to a granular structure. This specimen shows a still higher deviation (+14). The colour of the ash shows that the coal is ferruginous and the specimen is comparable with F. 141 from Bokaro which is a granular coal interpreted after analysis of the ash as a ferruginous coal of durain with vitrain, also with a high deviation (+8 to +11).[1] The South Karanpura specimen N. 192 may thus be regarded as ferruginous durain (with visible vitrain), but on account of the presumed abnormal composition of the ash as indicated by the high deviation it will be eliminated from further discussion as a typical durain, as also will N. 195 of carbonaceous shale.

To show the relationship between specific gravity and ash contents the data to be discussed have been plotted in two graphs on Plate 9, one (figure 1) representing the caking durains of Table 1, and the other (figure 2) the non-caking durains of Table 2. As might be anticipated the spots representing the various analyses are much more irregularly scattered than in the comparable graph illustrating the Kurasia and Bokaro series in the first paper (*Rec. Geol. Surv. Ind.*, LX, Plate 26): for these analyses represent coals from several different coalfields, each with its own value of *k*. However, on each plate a line has been drawn representing an average value of *k* for the particular class of coal, the figure adopted for the caking coals being 1·27, and that for the non-caking coals being 1·30. As in Bokaro (*see* the plate referred to) the spots representing the granular coal (N. 192) of South Karanpura would lie well above the line corresponding to a colloidal suspension of ash in vitrain,

[1] *Rec. Geol. Surv. Ind.*, LX, pp. 322, 336 (1928).

as also would the spots representing the carbonaceous shales (N. 195) of South Karanpura, the position of the spots supporting the view that the carbonaceous shale is a coarse suspension (mechanical mixture) and not a colloid system (suspensoid). The data for N. 192 and N. 195 are, however, not shown in Plate 9.

III.—DISCUSSION OF DATA.

In Tables 1 and 2 the analyses are arranged in order of specific gravity on an ash-free basis, and not in order of the actual specific gravity of the specimens as determined. The ash content of durain is, however, an essential portion of the coal and consequently if one wishes to form an idea of the composition of durain, one must utilise the data as determined. In the following table the caking durains are arranged in order of ash contents.

TABLE 3.—*Caking durains.*

Coalfield.	Register No.	Moisture. M.	Volatile matter. V.	Fixed carbon. C.	Ash. A.	Specific gravity. G.	Fuel-ratio. $\frac{C}{V}$
		Per cent.	Per cent.	Per cent.	Per cent.		
1. Wankie	Af. 151*	1·00	21·20	63·98	13·82	1·463	3·02
2. Giridih	N. 332	0·46	22·56	56·75	20·23	1·484	2·51
3. Raniganj	N. 218	0·85	21·75	52·72	24·68	1·538	2·42
4. Bokaro	23·966	0·98	22 05	37·60	39·37	1·65	1·70
5. Jharia	N. 237	0·54	15·90	43·52	40·04	1·682	2·74
6. Jharia	N. 243	0·80	19·92	38·49	40·79	1·683	1·93
7. Jharia	N. 253	0·36	18·91	38·72	42·01	1·731	2·04
	Average of 2 to 7	0·67	20·18	44·63	34·52	1·628	2·21

* Field No.

The following table shows the non-caking durains (excluding the granular durain and the carbonaceous shale from South Karanpura) arranged in order of ash contents :—

TABLE 4.—*Non-caking durains.*

——	Register No.	Moisture. M.	Volatile matter. V.	Fixed carbon. C.	Ash. A.	Specific gravity. G.	Fuel-rat o. $\frac{C}{V}$
		Per cent.	Per cent.	Per cent.	Per cent.		
1. Talcher	N. 330	5·90	34·42	52·83	6·85	1·373	1·53
2. Jainti	N. 329	4·16	26·00	52·54	17·30	1·483	2·02
3. Umaria	N. 327	5·99	21·36	40·48	32·17	1·680	1·89
4. Kurasia	26·639	4·10	19·10	43·52	33·28	1·64	2·31
5. Raniganj	N. 229	4·27	28·81	33·13	33·79	1·645	1·15
6. Kurasia	27·432	3·80	22·28	38·96	34·96	1·61	1·75
7. S. Karanpura	N. 193	2·02	22·68	31·68	43·62	1·749	1·39
8. S. Karanpura	N. 193	2·00	23·90	25·70	48·40	1·789	1·08
	Average of 2 to 8	3·76	23·45	38·00	34·79	1·656	1·62

In Table 3 the average composition of caking durain is obtained by averaging analyses 2 to 7, the Wankie analysis being excluded as not Indian. Whilst in Table 4 the average composition of non-caking durain is obtained by omitting the Talcher analysis, really because the Talcher specimen was exceedingly rich in fusain. The averages for caking and non-caking durains are compared below:—

——	Caking durain.	Non-caking durain.
	Per cent.	Per cent.
Moisture	0·67	3·76
Volatile matter	20·18	23·45
Fixed carbon	44·63	38·00
Ash	34·52	34·79
Specific gravity	1·628	2·656
Fuel-ratio	2·21	1·62

It will be noticed that the caking durains have lower moisture and higher fixed carbon than the non-caking ones, whilst the volatile matter, ash and specific gravity are closely similar. The fuel-ratio of the caking durains is substantially higher than that of the non-caking durains. These average analyses may be compared with the actual analyses of dull greasy-lustred coals or durain shown in Table 6, *Rec. Geol. Surv. India,* LX, p. 340.

If we deduce the specific gravity on an ash-free basis of these two average durains by using the equation

$$g_1 = g - \frac{a}{100},$$

we find that g_1 is 1·283 for the caking durains, and 1·308 for the non-caking durains. These figures have to be compared with the corresponding average values of k deduced from the corresponding

vitrains, which are 1·267 for the caking vitrains and 1·298 for the non-caking vitrains, showing a deviation of +1 (to the nearest unit — 0·01) in both cases.

The above data illustrate the composition of durain.

It is now desirable to consider the point that, in accordance with the first paper, durain is a colloid system in which vitrain acts as the dispersion medium to the ash contents as the disperse phase (suspensoid) with vegetable detritus as a second disperse phase (coarse suspension). It will be of interest to see whether when the analytical data are calculated to an ash-free basis the composition as thus deduced bears any close relation to the composition of the corresponding vitrains. We can hardly expect any close correspondence between the composition of a particular ash-free durain and the vitrain of the same field, and we shall probably find it desirable to compare the average data for ash-free durains with the average data for ash-free vitrains, averaging the data, as before, in two sets corresponding to the caking and non-caking durains respectively.

It is necessary first, however, to compare the ash-free durains field by field with the data for the corresponding ash-free vitrains. This is done in Tables 5 and 6.

If we now study the data for the caking durains and corresponding vitrain given in Table 5, we notice the following points:—

(1) Each durain has lower moisture contents than the corresponding vitrain.

(2) The volatile matter of durain is sometimes higher and sometimes lower than the volatile matter of the corresponding vitrain.

(3) The fixed carbon of durain is sometimes lower but usually higher than the fixed carbon of the corresponding vitrain.

(4) It follows from (2) and (3) that the fuel-ratio is sometimes lower and sometimes higher than the fuel-ratio of the corresponding vitrain.

(5) The specific gravity of durain is in two cases the same and in the remaining cases higher than the specific gravity of the corresponding vitrain. Considering only two places of decimals, the deviation varies from 0 to +5.

TABLE 5.—*Comparison of caking durains and*

Coalfield.	DURAIN.							
	Register No.	Moisture. M.	Volatile matter. V.	Fixed carbon. C.	Fuel-ratio. $\frac{C}{V}$	Specific gravity. G.	Specific gravity deviation.	Fuel-ratio deviation.
		Per cent.	Per cent.	Per cent.				
1. Bokaro .	23·966	1·61	36·37	62·02	1·70	1·256	0	—0·67
2. Jharia .	N. 243	1·35	33·65	65·00	1·93	1·275	0	—0·16
3. Giridih .	N. 332	0·58	28·28	71·14	2·51	1·282	+2	+0·80
4. Jharia .	N. 237	0·90	26·52	72·58	2·74	1·282	+1	+0·65
5. Raniganj B	N. 218	1·13	28·87	70·00	2·42	1·291	+3	+0·45
6. Jharia .	N. 253	0·62	32·61	66·77	2 05	1·311	+4	—0·05
7. Wankie .	Af. ·151	1·16	24·60	74·24	3·02	1·325	+5	..
	Average* of 1 to 6	1·03	31·05	67·92	2·19	1·283	+2(1·67)	+0·18

* No. 7 is omitted from the average, because it is not an Indian coal.

TABLE 6.—*Comparison of non-coking durains and*

Coalfield.	DURAIN.							
	Register No.	Moisture. M.	Volatile matter. V.	Fixed carbon. C.	Fuel-ratio. $\frac{C}{V}$	Specific gravity. G.	Specific gravity deviation.	Fuel-ratio deviation.
		Per cent.	Per cent.	Per cent.				
1. Kurasia .	27·482	5·84	34·26	59·90	1·75	1·260	—4	—0·25
2. Talcher .	N. 830	6·33	36·95	56·72	1·53	1·305	—2	+0·35
3. S. Karanpura	N. 193	3·87	46·32	49·81	1·08	1·305	+2	—0·63
4. Kurasia .	26·639	6·14	28·63	65·23	2 31	1·307	+1	+0·81
5. Raniganj R .	N. 229	6·45	43·52	50·04	1·15	1·307	+3	—0·22
6. Jainti .	N. 329	5·03	31·44	63·53	2·02	1·310	+4	+0·20
7. S. Karanpura	N. 193	3·58	40·23	56·19	1·39	1·313	+2	—0 32
8. Umaria .	N. 327	8·83	31·49	59·68	1·89	1·358	+8	+0·24
	Average* of 1 and 3 to 8	5·68	36·55	57·77	1·58	1·308	—2(1·57)	—0·10

* No 2 is omitted from the durain average because the specimen contained a high percentage of fusain.

corresponding vitrains on an ash-free basis.

Vitrain.				
Moisture. M.	Volatile matter. V.	Fixed carbon. C.	Fuel-ratio. $\frac{C}{V}$	Specific gravity. K.
Per cent.	Per cent.	Per cent.		
1·87	29·18	68 95	2·37	1·259
1·63	32·25	66·12	2·09	1·275
0·85	36 58	62·57	1·71	1·258
1·63	32 25	66·12	2·09	1·275
1·38	33·34	65·28	1·97	1·260
1·63	32 25	66·12	2·09	1·275
1·09	36·99	61 92	1·67	1·272
1·50	32·64	65·86	2·01	1·267

corresponding vitrains on an ash-free basis.

Vitrain.				
Moisture. M.	Volatile matter. V.	Fixed carbon. C	Fuel-ratio. $\frac{C}{V}$	Specific gravity. K.
Per cent.	Per cent.	Per cent.		
11·45	29·50	59·05	2·00	1·299
15·17	38·81	46·02	1·18	1·323
6 37	34 50	59·13	1·71	1·289
11·45	29 50	59·05	2·00	1·299
6·70	39 33	53·97	1·37	1·277
2·47	34·51	63·02	1·82	1·273
6·37	34·50	59·13	1·71	1·289
15·72	31·84	52·44	1·65	1·382
9·46	34·07	56·47	1·68	1·298

The average figures for the caking durains and corresponding vitrains are compared below :—

——	Average ash-free caking durain.	Average ash-free vitrain.
	Per cent.	Per cent.
Moisture	1·03	1·50
Volatile matter	31·05	32·64
Fixed carbon	67·92	65·86
Fuel-ratio	2·19	2·01
Specific gravity	1·286	1·267

When one considers the experimental errors inherent in the methods of proximate analysis, especially the difficulty of maintaining a uniform separation of volatile matter and fixed carbon, one sees that the average caking durain when calculated to an ash-free basis has substantially the same composition as the corresponding vitrain. This affords strong support to the conclusion arrived at in the first paper that durain is a colloid system with mineral matter as the disperse phase in vitrain as the dispersion medium. The only two significant differences in the two sets of average figures above are in the moisture and the specific gravity. The fact that the average specific gravity of durain is 0·02 higher than the average specific gravity of the corresponding vitrains means one of two things, either the ash contents of the durains examined are of abnormal composition due, for example, to high iron contents, or there is some other constituent of chemical composition close to that of vitrain but higher specific gravity in the vitrain. Reference to Table 1 will show that the colour of the ash of all the durains listed there is pale, so that it seems more likely that this average deviation of +2 is due to some additional constituent. It has already been admitted that durain, in addition to vitrain and the ash contents as a disperse phase, probably carries vegetable detritus (*e.g.* spores) in coarse suspension, and we see that we may now ascribe this average deviation of +2 (ranging from 0 to +5) with some probability to suspended vegetable detritus of higher specific gravity than the vitrain. If we are entitled to assume that the inclusion

of disperse phases in the vitrain has not affected the amount of moisture in the vitrain, and also that the enclosed vegetable detritus is devoid of moisture, then the amount of moisture in the ash-free durain gives a measure of the proportions of vitrain and vegetable detritus making up this ash-free vitrain. Two parts of vitrain to roughly one part of vegetable detritus (*i.e.* 33 per cent. of vegetable detritus) would reduce the average moisture from 1·50 to 1·03. Such a conclusion depends also on the assumption that none of the moisture is associated with the mineral matter.

If we next study the data for the non-caking durains and corresponding vitrains given in Table 6, we notice the following points :—

(1) With one exception each durain has lower moisture contents than the corresponding vitrain. The cause of the exception—Jainti—is unknown.

(2) As with the caking durains, the volatile matter of non-caking durain is sometimes higher and sometimes lower than the volatile matter of the corresponding vitrain.

(3) As with the caking durains the fixed carbon of non-caking durain is sometimes lower and sometimes higher than the volatile matter of the corresponding vitrain.

(4) As before, it follows from (2) and (3) that the fuel-ratio is sometimes lower and sometimes higher than the fuel-ratio of the corresponding vitrain.

(5) With two exceptions the specific gravity of the non-caking durains is higher than that of the corresponding vitrain.

The average figures for the non-caking durains and corresponding vitrains are compared below :—

——	Average ash-free non-caking durain.	Average ash-free vitrain.
	Per cent.	Per cent.
Moisture	5·68	9·46
Volatile matter	36·55	34·07
Fixed carbon	57·77	56·47
Fuel-ratio	1·58	1·68
Specific gravity	1·308	1·298

As with the caking durains we see that the average non-caking durain when calculated to an ash-free basis has substantially the same composition as the corresponding average vitrain, the only significant differences as before being lower moisture in the durain, but an average specific gravity higher than for the corresponding vitrain. The interpretation of these differences is presumably the same as with the caking durains, and if the lower moisture of the durain were an index of the proportion of vegetable matter in coarse suspension, then the proportion would be 3 parts of vitrain to 2 parts of suspended vegetable matter, *i.e.* 40 per cent. of vegetable detritus.

It is instructive also to compare the average figures for caking durains with the average figures for non-caking durains as follows:—

—	Average caking durain.	Average non-caking durain.
	Per cent.	Per cent.
Moisture	1·03	5·68
Volatile matter	31·05	36·55
Fixed carbon	67·92	57·77
Fuel-ratio	2·19	1·58
Specific gravity	1·286	1·309

From this we see that the caking durains show lower moisture, volatile matter and specific gravity and higher fixed carbon and fuel ratios than the non-caking durains. A reference to Table 7 on p. 202 of the second paper (*Rec. Geol. Surv. Ind.*, LXII) will show that these differences between caking and non-caking durains are parallel to the differences between caking and non-caking vitrains.

In comparing above the data for vitrains with the data for durains, arranged into two groups—caking and non-caking—I have been very careful to speak of the corresponding vitrain rather than of caking and non-caking vitrains. This is because the division between caking and non-caking vitrains on an ash-free basis does not correspond exactly with that between caking and non-caking durains on the same basis. Thus whilst all the vitrains corresponding to the strongly caking durains of Table 1 are also strongly caking, all the vitrains corresponding to the non-caking (or but slightly

caking) durains of Table 2 are not non-caking (or but slightly caking). Thus of the vitrains shown in Table 6 for comparison with non-caking vitrains, the caking properties are as follows :—

——	Moisture.	Caking properties.
	Per cent	
1. Kurasia	11·45	Does not cake or sinters slightly.
2. Talcher	15·17	Cakes very poorly.
3. South Karanpura	6·37	Cakes strongly.
4. Raniganj	6·70	Cakes strongly.
5. Jainti	2·47	Cakes strongly.
6. Umaria	15·72	Does not cake.

This means that in vitrain the upper limit of moisture for strongly caking properties is higher (> 6 per cent.) than with durains. From this we may deduce that apart from the effect of changes in the ratio of volatile matter to fixed carbon, there are two very important factors that may spoil the caking properties of a coal: one is hydration and the other is dilution by 'ash contents'. But if the moisture is very low, then no amount of ash consistent with the substance being still a coal (*i.e.* >50 per cent. ash) will destroy the caking properties.

Since the above was written, Dr. Fox has kindly supplied me with two analyses– one of durain and one of vitrain—from the Johilla river in the Sohagpur Coalfield, Rewa State, Central India. The analyses are as follows :—

——	Durain.	Vitrain.
	Per cent.	Per cent.
Moisture	6·94	16·76
Volatile matter	24·19	34·06
Fixed carbon	35·63	44·76
Ash	33·24	4·42
Specific gravity	1·643	1·424
Caking properties	Sinters slightly	Does not cake.
Colour of ash	Cream buff .	Isabella.

Reduced to an ash-free basis the results are as follows :—

——	Durain.	Vitrain.
	Per cent.	Per cent.
Moisture	10·39	17·53
Volatile matter	36·25	35·64
Fixed carbon	53·36	46·83
Specific gravity	1·380	1·332
Fuel ratio	1·47	1·65
Deviation	+5	..

The similarity of this Johilla river durain in ash contents and specific gravity to those from Kurasia and Raniganj (Nos. 4, 5 and 6) shown in Table 4 is very striking. The differences in composition, specific gravity and fuel-ratio between this durain-vitrain pair are in the same direction as in the durain-vitrain average figures given on page 371.

These figures have been received too late to be incorporated in the preceding tables, but the durain finds its place in the diagram forming figure 2 on Plate 9.

V.—SUMMARY.

1. In a previous paper it was shown that in two sets of coals of the vitrain-durain series, obtained respectively from the Kurasia and Bokaro coalfields, the relationship between specific gravity and ash contents of any specimen is expressed by the rule

$$a = 100\,(g\text{-}k),$$

in which a is the ash contents, g the specific gravity of the specimen, and k the specific gravity of ash-free coal (*i.e.* pure vitrain) for the field.

2. In a second paper a study is made of vitrain from 20 coalfields and localities ranging in age from Barakar to Siwalik, the data obtained being compared, after reduction to an ash-free basis, with the aid of the rule in paragraph 1 above,

3. This study showed that in the vitrains examined moisture increases with specific gravity, and that most vitrains cake if they contain less than 9 to 10 per cent. of moisture, and do not cake with moisture in excess of this figure.

4. The volatile matter was found to increase with the specific gravity in some series of vitrains, and to decrease in other series, whilst the fixed carbon varies in the inverse manner to the volatile matter. There is no correlation between caking properties and either volatile matter, fixed carbon, or fuel-ratio.

5. In the first paper it was shown that durain must be regarded as a colloid system in which there are two disperse phases, namely ash contents (suspensoid) and vegetable detritus (coarse suspension), in vitrain as the dispersion medium.

6. In the second paper the conclusion was drawn that in vitrains we are dealing with systems in which the relationship of moisture to moisture-free vitrain is a colloidal relationship comparable with that between the water imbibed by a dry gel (*e.g.* casein) and the dry gel itself.

7. In the third paper, the present one, a study is made of picked specimens of silky and dull (greasy-lustred) coals from 10 coalfields (9 Indian and one South Rhodesian) all of Gondwana age. The data of specific gravity and proximate analyses are arranged into two tables according to whether the coal proved strongly caking or non-caking (including poorly caking coals).

8. A comparison of the average data for caking durains with average data for non-caking durains shows that the caking durains have lower moisture and volatile matter, higher fixed carbon and fuel-ratios and almost identical ash contents. As with the vitrains the higher moisture of the non-caking durains is accompanied by a higher specific gravity. The data are as follows :—

——	Caking durain.	Non-caking durain.
	Per cent.	Per cent.
Moisture	0·67	3·76
Volatile matter	20·18	23·45
Fixed carbon	44·63	38·00
Ash	34·52	34·79
Specific gravity	1·628	1·656
Fuel-ratio	2·21	1·62

9. A comparison is also made, with figures both analytical and of specific gravity reduced to an ash-free basis, of each durain with its corresponding vitrain. If the conclusion of the first paper be correct (see paragraph 1 above), then the composition of ash-free durain should be that of the vitrain of the same locality except in so far as the durain carries suspended vegetable matter the composition of which might differ substantially from that of the containing dispersion medium of vitrain. The following data comparing the average composition on an ash-free basis of the caking durains from 5 coalfields with the average composition of the corresponding vitrains is therefore of great interest :—

—	Average ash-free caking durain.	Average ash-free vitrain.
	Per cent.	Per cent.
Moisture	1·03	1·50
Volatile matter	31·05	32·64
Fixed carbon	67·92	65·86
Fuel-ratio	2·19	2·01
Specific gravity	1·286	1·267

They appear to afford very strong support to the conclusion of the first paper set out in paragraph 1 above.

10. The similar data for the ash-free non-caking durains from 7 coalfields and the corresponding vitrains are compared below :—

—	Average ash-free non-caking durain.	Average ash-free vitrain.
	Per cent.	Per cent.
Moisture	5·68	9·46
Volatile matter	36·55	34·07
Fixed carbon	57·77	56·47
Fuel-ratio	1·58	1·68
Specific gravity	1·309	1·298

These data also afford strong support to the conclusion of the first paper set out in paragraph 1 above.

11. The fact that the ash-free durain (including the suspended vegetable detritus) has a composition so close to that of the corresponding vitrain seems to indicate that for the purpose of proximate analysis this suspended vegetable matter itself must have a composition very close to that of the vitrain

12. The most important respect in which these two average ash-free durains differ from the corresponding average vitrains is in the somewhat higher specific gravity, equivalent to a content of 2 per cent. of ash in the caking durains and of 1 per cent. of ash in the non-caking durains. The explanation of this is not known: but it is suggested that it is due to the effect on the specific gravity of the vegetable detritus in suspension having a higher specific gravity than the vitrain.

13. The result of this study is to confirm the conclusion of the first paper, namely that durain is a colloid system in which vitrain plays the role of the dispersion medium and the ash contents the role of the disperse phase (suspensoid), whilst the vegetable detritus may be regarded as a second disperse phase (coarse suspension).

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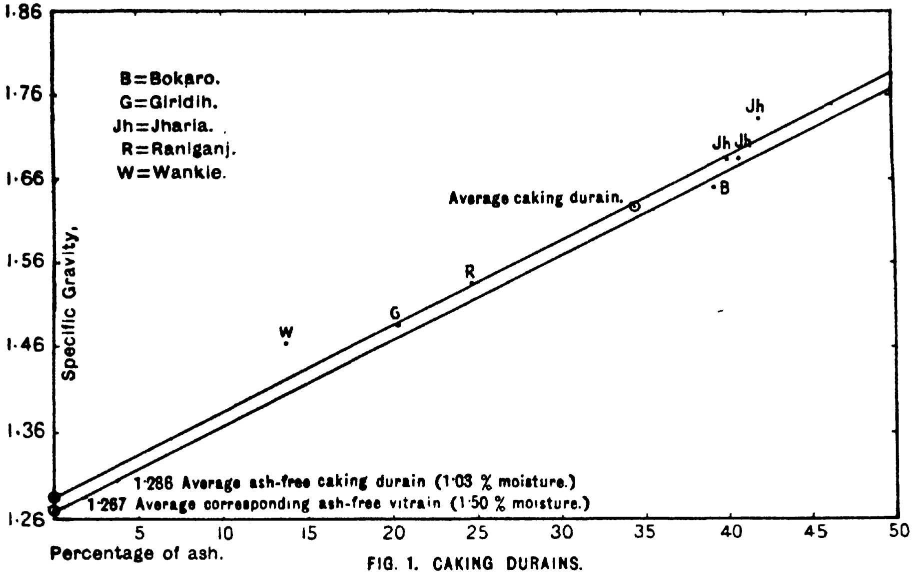

FIG. 1. CAKING DURAINS.

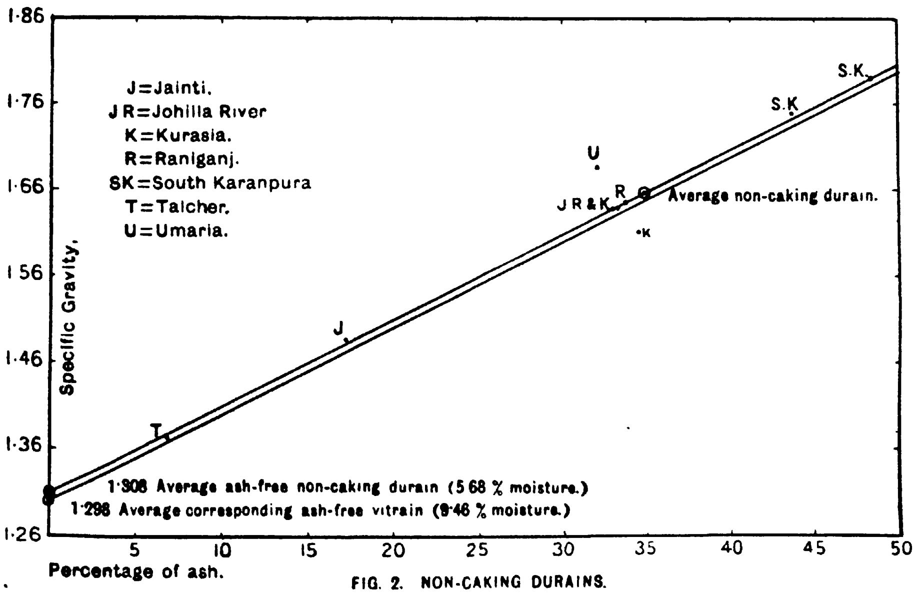

FIG. 2. NON-CAKING DURAINS.

G. S. I. Calcutta.

DIAGRAMS SHOWING SPECIFIC GRAVITY AND ASH CONTENTS OF GONDWANA DURAINS.

In each diagram the upper line represents the average position of the points plotted, whilst the lower line represents the position as it would be if the origin were the point representing the specific gravity of the average of the corresponding ash-free vitrains.

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SOME ASPECTS OF MODERN OILFIELD PRACTICE. BY C. T. BARBER, M.SC., F.G.S., M. INST. P.T., *Assistant Superintendent, Geological Survey of India,* Resident Geologist, Yenangyaung. (With Plates 10 to 18.)

CONTENTS.

INTRODUCTION.

THE following discussion of two important aspects of modern oilfield practice is based on five months' study leave spent in the United States of America, from June to November, 1928. During that period the principal oilfields in the Mid-Continent, Wyoming, California, and West Texas areas were visited, and in addition to studying drilling and production problems in these areas I enjoyed the privilege of discussing them with a great number of American engineers and technologists. I have also drawn freely on the great wealth of published literature on these subjects in the United States. The sources of information being so numerous and diverse it has not been practicable, in the text, to give detailed references to them, and such references have only been given where any particular work has been specifically quoted. It is, however, my desire to place on record my appreciation of the most generous co-operation I received from American engineers and technologists and more particularly from the officers of the United States Bureau of Mines, my association with whom was the most profitable of my experiences in the United States.

Problems connected with the winning of oil, fall naturally under two headings; the drilling and completion of wells, and methods of production. The most important advance of the past decade in the technique of drilling is the elaboration of the rotary system and the consequent modification of casing policies, which constitutes one of its principal advantages; while a realisation of the function of gas in the recovery of oil, leading to the evolution of production methods that promote the utilisation and conservation of gas, is the outstanding achievement of production engineering. These subjects are discussed under the headings 'Rotary Practice' and 'Recovery' respectively. My aim in these sections has been to summarise as far as possible existing knowledge on these subjects, to outline the extent to which this knowledge is successfully applied in the United States of America, and to discuss the possibilities of its successful application in Burma.

ROTARY PRACTICE.

The principal advantages and disadvantages of the rotary, as compared with the cable-tool system, are dependent on the continuous circulation of mud-laden fluid during rotary drilling. This mud fluid performs three essential functions during the drilling of the well:—

(1) It carries the 'cuttings' (*i.e.*, the comminuted fragments of rock) to the surface.
(2) It keeps the hole open without the immediate use of casing.
(3) It cools the drilling bit.

An incidental, but an extremely important function, is its ability to seal up porous formations through which the tools are drilling.

Rotary system conducive to rapid drilling.

The advantages of the rotary system are dependent on the second of the essential functions of mud fluid enumerated above and upon its incidental function in sealing up the porous formations through which the bit is drilling. Essential function No. 2 results, particularly in soft incoherent deposits (the 'cavey formation' of drillers), in much greater rapidity of drilling than is possible with standard tools and also contributes to a great saving of pipe.

The greater progress made in rotary drill holes is due to two causes, the quicker excavation of the formation by rotary tools,

and the ability to drill without immediately lining the hole. When drilling with cable tools in soft incoherent formations it is necessary to insert and lower casing after drilling every additional few feet of hole; whereas, owing to the plastering effect of mud fluid in rotary drill holes, and to the pressure of the column of fluid, both of which prevent the walls of the hole from caving in, it is usually possible to drill as much as 3,000 feet of hole without inserting casing.

In cable-tool holes also, the caving of the formation frequently results in the 'freezing' of the pipe, making it impossible to lower this casing to the desired depth. It is then necessary to insert a smaller string of casing inside the 'frozen' string and to proceed with the restricted hole. Repetition of this process rapidly results in so reducing the diameter of the hole that it may be impossible to carry a cable-tool hole to the required depth. In rotary practice, however, the only limitation on the depth to which a string of pipe can be carried is the collapsing strength of the pipe, and it is this ability to 'land' long strings of large-diameter pipe, even more than the financial saving in the cost of pipe, that is the principal advantage of the rotary system. This point is of particular advantage where the depth to the producing formation is considerable. Where the upper formations are unproductive a large hole can be drilled rapidly and cheaply to the isolation point by using the rotary system, from which point it can be continued by rotary or standard tools as circumstances dictate. Under these conditions of depth the use of the rotary system is clearly indicated.

Casing policies in cable and rotary tool wells.

It is frequently desired, however, to drill through shallow producing zones for deeper production. In such cases all principles of conservation demand that the primary consideration shall be adequate protection of the upper producing sands from fluid migration. In the past, the principal, and frequently the only consideration, has been the protection of oil-producing sands from water. In cable-tool practice this protection is effected by 'landing' and cementing a string of casing, called 'the water string', above the first productive horizon. The hole is then continued, with a new and smaller string of pipe, until the next water-producing horizon is approached. This smaller string is in turn cemented to protect the producing horizons, between the 'water string' and the new water sand, from the upward migration of water. The hole is then again continued with a smaller string of casing, which is in

turn cemented above the next oil-producing horizon. A still smaller string of casing is then inserted and carried through barren and oil-producing sands until it is again necessary to protect such sands from the influx of water from below. This process is repeated till the desired depth is reached or until the continued restriction of the size of the hole so reduces the diameter that drilling becomes impracticable or the hole inadequate for production. Where a large number of producing horizons interspersed with water sands exist the point is soon reached when the hole becomes too small, and this fact, together with the cost of so many strings of pipe, has been regarded as the principal disadvantage of the cable-tool system. It is now realised, however, that, even with a rigorous observance of this casing policy, the resulting conditions are not ideal. In a completed well, conditions can be considered ideal only when the fluid content (be it oil, water or gas) of every sand, other than that from which fluid oil is to be taken, is isolated within the sand in which it originates. In modern cable-tool practice, attempts are frequently made to achieve this isolation by placing a continuous column of cement behind the pipe; such cementation being effected with or without preliminary 'mudding'. In other instances, notably in the Tonkawa and Garber fields of Oklahoma, a column of mud fluid is maintained behind the casing in cable-tool holes and this practice is believed by many authorities to be effective in preventing fluid migration behind the pipe.

It is doubtful if the operation of 'back cementation' in cable-tool holes is invariably or usually successful, particularly in incoherent formations and depleted fields. For this reason, 'back cementation' in cable-tool wells, unless the hole is previously mudded, is frequently combined with, instead of substituted for, the comprehensive casing policy outlined above. In rotary drill holes, however, the sealing action of the mud fluid during drilling, combined with the greater resultant success of 'back cementation', are believed to be effective in preventing fluid migration behind the casing. Mud fluid and cement, therefore, are largely used in rotary drill holes, as alternatives to casing, for the protection of upper producing horizons, thus making it permissible to 'land' long strings of large-diameter pipe above deep producing horizons, even when the latter are overlain by several higher producing sands. The extent to which this practice is followed and, to which

it is believed to be successful, in various American fields is discussed below.

Isolation policies in the Tonkawa and Garber fields, Oklahoma.

There are a remarkable number of oil-producing sands in the Tonkawa and Garber fields and this has led to a system of multiple well locations. Productive sands of varying thickness occur between depths of 900 to 4,260 feet and are tabulated for both fields below :—

Producing sands in the Garber field.[1]

Depth.	Thickness.	Production.	Horizon.
Feet.	Feet.	Barrels.	
825	8	....	Winfield.
1,050	20	20—150	Hoy sand.
1,360	10	....	
1,470	15	20—150	Above Foraker.
1,740	10	....	
2,020	12	15—100	U. Pennsylvanian.
2,100	12	....	
2,200	5	25—200	
2,315	20	....	U. Hoover.
2,500	15	....	M. Hoover.
2,560	35	....	L. Hoover.
2,750	45	....	Endicott.
3,025	25	....	U. Tonkawa.
3,070	50	....	L. Tonkawa.
3,600	90	....	Layton.
4,160	20	....	Oswego-Big-Lime.
4,250	?	....	Wilcox on flanks of fold.
4,260	50	5—10,000	Siliceous Lime.

[1] 'Oil and Gas in Oklahoma.' Oklahoma Geological Survey Bulletin No. 40-H., p. 31.

Producing sands in the Tonkawa field.[1]

Depth.	Thickness.	Production.	Horizon.
Feet.	Feet.	Barrels.	
725—825 Five sands .	5—10	5—12†	Above Neva.
1,350	6	small	
1,500	17	....	Bet. Foraker & Elgin.
1,750	18	10—30†	(Newkirk).
1,800	16	small	Upper Hoover.
1,825—75 . . .	48	....	Middle Hoover.
1,950	25	6—12†	Lower Hoover.
2,025	5	50—250	Carmicael.
2,100	6	100—600	Endicott.
2,400—500 . . .	100	1,000—3,000	Tonkawa.
4,100	285	Avr. 250	Wilcox.

† Million cubic feet of gas.

The discovery well in the Garber field was brought in at 100 barrels in the Hoy Sand at 1,130—1,156 feet in September, 1917 and was followed by keen competitive drilling, which has also marked the more recent discovery of deeper sands.

The Tonkawa field dates from June, 1921 when a well was completed at 2,661 feet with an initial production of 3,300 barrels from the Tonkawa sand. A year later a well was brought in at 800 barrels from the Hoover sand in another part of the field, and rapid development in the Pennsylvanian formation followed in 1922-23. In April, 1924 the development of production from deeper horizons commenced with the completion of Slick No. 1-A down to the Wilcox sand. Production above the Wilcox sand is taken from five main horizons, including a zone 750 feet in thickness the top of which is 900 feet below the Permian-Pennsylvanian contact. The Tonkawa sand is found at 2,450—2,500 feet and is the deepest producing horizon in the Pennsylvanian formation. The only prominent

[1] *Op. cit.*, p. 36.

sand between the Tonkawa and the Wilcox is the 3,100 feet or Layton sand, which is a water sand in the Tonkawa field.

In addition to the oil-producing sands mentioned above there are three well-defined gas horizons. The first or shallow gas horizon is the so-called 800-foot gas sand, a zone about 150 feet in thickness, which yielded wells with an average 'open' flow of 7 million cubic feet per day with an average rock pressure of 260 lbs. per sq. in. The second important gas horizon is found 400 to 500 feet below the Foraker limestone and about 1,500 to 1,600 feet below the surface. The initial free flow of a well in this sand was 5¼ million cubic feet and the rock pressure 620 lbs. In many parts of the field, however, water was found in this sand. The third gas horizon is found at depths of from 1,600 to 1,800 feet. One well completed in this sand had an initial open flow of 74½ million cubic feet and a rock pressure of 650 lbs.

In addition to the Layton sand there are four other important water sands in the Tonkawa field, the first of which lies near the base of the first shallow gas zone. The second, 100 to 150 feet above the Upper Hoover sand, carries gas where it occurs high up on the structure. The third is the Middle Hoover sand and the fourth is situated some 200—300 feet above the Tonkawa sand. This last is the most persistent water sand in the field and carries water under a high head.

The policy of operators in these fields has been to drill separate wells to produce from the different sands; and in the areas in which several sands are productive there are as many as five or six wells on one location—a location being 10 acres—giving, except for irregularities in the exact positions of the various wells in the individual plots, a spacing of 660 feet between wells producing from any one horizon.

Many of the wells sunk down to the Hoover sands were drilled with standard tools, but most of the deeper wells have been drilled with rotary tools. The casing policy for the shallow cable-tool wells has not been uniform or systematic, particularly in the early competitive stages of the development of the Garber field. At that time many operators carried each string as far as possible in each individual well, 'landing' it where possible, in order to effect the isolation of a formation, and filled up behind the pipe with mud fluid to protect the upper oil and gas sands. More recently, particularly in the Tonkawa field, it has been the policy of some

operators to 'land' strings of casing above and below each of the productive sands that have been drilled through, but this casing policy is obviously impracticable when drilling for production from greater depths, and in such cases, cementation in rotary drill holes has been employed for the protection of the upper horizons.

The practice when drilling with the rotary system for production from depth—to the Hoover sands and lower—has been to set and cement a 'conductor' string at about 50 or 60 feet and then to drill down to an isolation point above the horizon from which it is intended to obtain oil. The well is then cemented using from 150 to 600 sacks of cement, cementing back in most cases to above the Hoover sand and in some cases back to the shoe of the 'conductor' string. In other cases in the Tonkawa field the amount of cement used is calculated to form an annular column of cement between the casing and the walls of the hole, from the shoe of the casing only to the point below which there would be a danger of the casing collapsing if it were not so protected, mud fluid has then been relied upon to protect the upper horizons. In the Garber field, wells drilled to the Wilcox horizon are usually carried down to below the Layton sand, which carries water, and cemented at 3,800 feet or thereabouts with 800–900 sacks of cement, which in most cases rises up behind the casing to 1,500 feet. The method of testing this cement work is to bail out and take fluid levels, or sometimes to ascertain whether the hole is dry at the cementing depth; but no effort is made to determine the extent to which the cement has reached the desired level behind the casing.

The technologists familiar with the fields believe that these methods have been successful in protecting the upper sands and in preventing fluid migration in the hole, even where cement is placed behind the water string only from the shoe to the point below which there would be a danger of the casing collapsing if it were not so protected. This belief is based on the fact that the upper producing sands are still free from water and also that in some instances where the companies have tried to obtain production from the upper sands, which have been drilled through, they have found them to be effectively sealed off, production only being secured with difficulty.

Californian isolation policies.

As a result of many years experience and study of rotary practice, the California State Mining Bureau, in co-operation with the producing companies, has adopted a two-string programme for rotary drill holes. A short conductor string is 'landed' through the surface detrital

deposits and cemented. The first water string is then set above the first horizon yielding oil in commercial volume. The second water string is cemented above the horizon from which the well is intended to produce, all intermediate sands being protected by mud fluid and cement.

The operation of this policy is exemplified by the development of the Santa Fe Springs oilfield, of which the productive zones and intermediate water sands are tabulated below.

Depth.	Zone.	Thickness.	Initial production in barrels.
2,000 feet . . .	Gas zone . . .	500 feet	50—100*
3,470 „ . . .	Foix zone (oil) . .	180 „	3,000—7,000
	Water sand		
3,650 „ . . .	Bell zone (oil) . .	300 „	3,000—4,000
	Water sand		
4,020 „ . . .	Meyer zone (oil) . .	830 „	6,000
6,100 „ . . .	Buckbie zone (oil) . .	?	10,000 (?)

* Million cu. ft. of gas.

Wells originally drilled to reach the Foix zone were carried down to the top of the zone and the casing cemented at that point. With few exceptions, no difficulty was experienced in drilling with the rotary tools through the upper gas zone, the rock pressure of which was estimated at 500 lbs. per sq. inch.

On the discovery of the Bell zone, wells, which were drilled to produce from it, were isolated above the Foix and again above the Bell. When the Meyer zone was developed, the two-string policy was still adhered to and wells drilled to this zone were isolated first above the Foix zone and again above the Meyer, leaving the Foix and Bell zones and their intermediate water sand behind the same string of pipe. In addition to 'mudding', these last two zones were protected by 'back cementation' from the isolation point above the Meyer zone, sufficient cement being used to cement back at least to the top of the intermediate water sand, and in many cases to the shoe of the previous string.

On the recent discovery of the Buckbie zone it was considered inadvisable to drill wells to this depth, leaving the Foix, Bell and Meyer zones and their intermediate waters behind the same string of pipe, as this procedure would involve 'back cementation' for 2,400

feet from the top of the Buckbie zone. The two-string policy, however, has been adhered to and the first isolation in wells drilled to the Buckbie zone is made above the Meyer ; the Foix and the Bell zones being protected by 'mudding' and cementing, 600 feet of cement being placed behind the pipe. The second isolation is made above the Buckbie sand where a string of pipe is landed, and from this point the pipe is cemented up as far as the shoe of the previous string. This policy was decided upon because of the great distance, for 'back cementation', between the Buckbie and Foix zones; the reduced value of the Bell zone and to a greater extent of the Foix zone; and the comparatively short length of 'back cementation' required to protect them. On 1st August, 1928 the production statistics of the Foix, Bell and Meyer zones were as follows :—

Foix zone	9 wells	1,440 barrels.
Bell zone	76 wells	6,780 barrels.
Meyer zone	221 wells	31,012 barrels.

It is believed by the engineers of the California State Mining Bureau and by the technologists of the leading companies operating in the Santa Fe Springs field, that these policies have been effective in protecting the productive zones from water infiltration and fluid migration. Writing on this subject in 1923, Mr. J. B. Case, Chief Deputy Supervisor of the California Department of Petroleum and Natural Gas, summarised the water conditions in this field as follows :—

> 'Little direct effort has been made to determine the exact stratigraphic position of water sands in the drilling of wells in the Santa Fe Springs Field excepting as water has been noted in wells when being tested or being put on production. Comparatively few wells have developed any water trouble. The production from most of the wells is clean. This may be due to the high degree of efficiency obtained in cementing strings ; or the back pressure of the well may prevent any water which otherwise might have access to the well, from entering.[1]

The Foix and, to a large extent, the Bell zones have subsequently become water bearing, but it is believed by the technologists familiar with the field that this is due to the encroachment of edge waters in the productive sands themselves and not to faulty isolation methods.

The development of the Midway Sunset field, in the San Joaquin Valley area, also illustrates the same policy. In this area it has

[1] Case, J. B. 'Report on the Santa Fe Springs Oil Field,' California Oil Fields, Vol. 8, No. 11, p. 17.

been the practice to set a string of casing above the first oil-sand and to continue drilling to the top of the sand from which it is intended to produce, where a second string of pipe is cemented, after preliminary 'mudding'. From the following table, shewing the productive zones and water sands in this field, it will be seen that the formations cased off behind the second string include, in some instances, as many as three oil zones and three water sands, one of which yields a free flow of water. As far as can be ascertained no difficulty was experienced in controlling this high pressure water sand by the use of mud fluid and cement.

Productive zones and water sands in the Midway Sunset Field.

	Thickness Feet.
Fine water sand	30—60
Top oil zone	50—70
Upper intermediate water sand	35—60
Kinsey oil zone	175—205
Tar sand	30—45
Big Flowing Water	95—140
Wilhelm oil zone	130—170
Gusher oil zone	90—?
Califroleum oil sand	110—?
Butress sand	?

Approved 'mudding' practice.

In all instances, the California State Mining Bureau requires that mud fluid of not less than 70 lbs. per cubic foot shall be used whilst drilling wells and that the mud column shall be maintained to the surface at all times. In addition to the 'mudding' of the formation thus effected during the process of drilling, the Bureau requires that, before cementing, the formations to be isolated behind each string of casing shall be 'mudded' in open circulation till the loss of fluid per 700 feet of hole does not exceed one barrel per hour. This circulation of mud fluid is witnessed by the engineers of the Bureau, who specify the amount of cement to be used subsequently, and also test the final cementing. Where strings are not 'cemented back' to the surface, or to the shoe of the previous string, it is recommended by the Bureau that the column of mud fluid behind the pipe should be maintained to the surface. This recommendation is made because the sealing action of mud fluid is believed to be permanent only

when the pressure of fluid in the hole exceeds the internal pressure of the formation.

It is believed by the majority of Californian technologists that this casing policy is successful in isolating the fluid content of all sands within the sand in which it originates. This condition is superior to that in the majority of cable-tool wells, particularly in those in which large quantities of cement have not been placed behind the casing.

Control of high-pressures in rotary drill holes.

Another advantage of the rotary system is the ease with which high-pressure oil and gas sands can be controlled in wells drilled by this method. It is usually, though not invariably, found that the pressure of oil and gas sands is proportional to their depth; it frequently approximates to the pressure of a column of water of equal depth. There is a widespread belief among oil men that this relationship is an invariable one, but this is not so. In many fields there is no essential relationship between the two, but it so frequently happens that the two pressures approximate to one another that, in the absence of any reliable method of computing rock pressures in unproved territory, the approximation forms a useful guide for such estimates.

In cases where the rock pressure of sands does not exceed the hydrostatic head of a column of water of equal depth it is clearly possible to control such sands by the maintenance in the hole of a column of fluid the specific gravity of which is greater than that of water. The specific gravity of mud fluids used in rotary practice varies from 1·05 to 1·8. It is theoretically possible, therefore, to control pressures 80 per cent. in excess of their anticipated magnitude. Such pressures are rarely encountered and mud fluid in excess of 94 lbs. per cubic foot (sp. gr. 1·51 approximately) is rarely used. The factor of safety of 50 per cent. afforded by the use of such mud is, under many circumstances, by no means excessive. This fact is particularly true when drilling into high-pressure gas-bearing formations as the gas 'aerates' the mud fluid, making it lighter and thereby reducing the pressure on the sand. This process is known by the drillers as 'cutting' or 'feathering' of the mud. Another way in which the pressure on the formation is sometimes reduced is by allowing the column of fluid to fall below the top of the hole. This drop sometimes occurs when the drill pipe is pulled out of the hole, as the volume of fluid required to fill the hole is then increased

by the volume of drill pipe extracted. In good practice the column of fluid is at all times maintained to the surface, but most of the recent 'blow-outs' in California, including the serious fire that occurred in the Santa Fe Springs field at the time of my visit, are attributable to negligence in this respect.

Use of heavy minerals.

The extent to which a mud fluid is 'feathered' depends on its viscosity or 'thickness'. It is possible to mix a 100 lbs. (per cubic foot) mud fluid using good quality clay and water, but such a fluid is so thick that it is difficult to handle with the rotary pumps and in addition it is readily 'feathered'. For this reason, when heavy mud fluids (anything in excess of 85 lbs. per cubic foot) are required, it is usual to increase their weight by the admixture of some heavy mineral constituent. The two heavy minerals most adapted to this use are barytes and hematite, both of which greatly increase the weight of mud fluids without appreciably increasing their viscosity. In Californian practice, the use of hematite in preference to barytes is attributable to the fact that the former is more readily available, but the majority of technologists believe that barium sulphate, particularly in its amorphous form, is the better substance. The disadvantages in the use of hematite are:—

(1) Its characteristic red colour, which is liable to mask oil indications in prospecting wells.

(2) It is difficult to obtain entirely free from silica, which acts as an abrasive, causing excessive wear of the casing and drill pipe.

(3) It settles rapidly unless continually agitated, and sometimes 'freezes' the drill pipe.

(4) Some authorities claim that it is liable to set up chemical or electrical reactions and so lead to corrosion of casing.

In all four respects, barytes is superior to hematite. The colour of barytes-weighted mud is lighter than that of ordinary mud fluid. Barytes is more easily obtained in a pure form, free from silica, and it remains in suspension longer than hematite (the amorphous variety of barium sulphate remains in suspension longer than the ordinary clay constituents of mud fluid). Barytes is an extremely inert substance and actually protects the casing from corrosion..

Weighted mud fluids have been extensively employed in Burmese rotary practice, but in several deep tests in the Yenangyaung

field their use has proved entirely inadequate to prevent excessive caving or 'heaving' of the formation. Similar difficulties have been combated in the United States by the use of 'wire line bits', which obviate the necessity of withdrawing the tools from the hole except at rare intervals; and by reversing circulation. It is possible that some special technique along these lines might contribute to the successful negotiation of the difficulties met with in Burma.

Disadvantages of the rotary system.

The principal disadvantages of the rotary system are :—

(1) The inaccuracy of rotary drill logs.
(2) The contamination by mud fluid of low-pressure producing formations.
(3) The deviation of rotary drill holes.

Of these, the first and second are due to the continuous circulation of mud fluid. As previously stated, one of the essential functions of the mud fluid used in rotary drilling is the removal of comminuted fragments of rock from the hole. This function is adequately performed under normal conditions by mud fluids weighing more than 70 lbs. per cubic foot, but the identification of the 'cuttings' cannot be carried out with sufficient adequacy for the preparation of a reliable log of the formations penetrated by the drill. This difficulty is now largely surmounted by the extensive use of coring devices, the perfection of which is the most important recent development in rotary practice. There is now a large selection of core barrels for use in rotary drilling on the market, including types suitable for taking cores in all the various formations encountered in oilfield practice. Their use by experienced drillers involves no more risk of drilling accidents than drilling with ordinary fish-tail or rock bits, and little reduction in the speed of drilling. In Californian practice, it is usual to take cores in the vicinity of all points at which an isolation is desired to choose a suitable formation in which to 'land' and cement the casing, and also to take continuous cores in the oil-bearing horizons. This practice has led to greatly improved knowledge of conditions in the oil-producing zones, and constitutes one of the principal advances in modern rotary practice.

Inaccuracy of rotary drill logs.

Use of core barrel.

A disadvantage, which is not entirely surmounted by coring, is the failure to recognise the fluid content of sands in rotary drill wells. The sealing action of mud fluid prevents the recognition of water sands, which are rarely recorded in the logs of rotary drill holes, and low-pressure oil and gas sands are frequently overlooked. It has been found in American practice that cores do not give satisfactory information on these important points. Owing to the presence of mud fluid during drilling it is usually impossible to recognise water in a core and, while even small quantities of oil can usually be detected by a solution test, reliable estimates of the potential production of an oil-sand cannot be made from a rotary drill hole. In the Mid-Continent, a device known as a formation or sand tester has been successfully used to supply the required information. The following description of this device, and of its mode of operation, and also the illustration comprising Plate 10 are taken from the manufacturer's descriptive circular :—

Use of formation tester.

'One of the greatest drawbacks to rotary drilling is the difficulty of testing sands encountered. There is a certain amount of danger in mudding off a producing sand when drilling with rotary tools because of the mud fluid used to remove the cuttings from the bit.

With the .... Sand Tester each sand, as it is encountered, can be tested and an accurate estimate made of the amount of oil and gas.

It is a common practice when drilling the wells with rotary tools, to drill ahead with a bit of smaller size than the one used to finish the hole. From time to time the hole is reamed down to the final size if no producing sand is found. This gives the operator a chance to ream down to a place where the casing can be properly set when a producing sand is encountered. The reduced hole is usually 7⅞ or smaller while the final hole is 9¼ or larger. When the small bit encounters a sand it is only necessary to drill into the sand and wash out the reduced (rat hole) hole.

After the hole is in proper condition, that is, a sand has been encountered by the small bit and the large hole has been reamed down to a proper seat, which is generally anywhere from three to fifty feet above sand, the .... sand tester is then run in on the drill pipe and a test made.

The sand tester consists essentially of a tapered packer below which is a perforated pipe extending into the rat hole and conducts the oil or gas above the packer where there is a stop cock enclosed in a steel case that can be opened or closed by turning the drill pipe one quarter turn. The drill pipe is run in with the stop cock closed leaving the drill pipe dry. After the packer is seated the stop cock is opened. The same condition now exists as if casing had been set and the hole bailed out. This allows the fluid in the sand to enter the drill pipe giving a sample of whatever is in the sand.

If gas is encountered it will blow through the drill pipe and if any fluid is in the sand it will flow into the drill pipe and can be taken out by closing the stop cock and removing the drill pipe. When oil or salt water are withdrawn with the drill pipe, especially if thirty or forty joints are taken out, the gas causes the oil or salt water to flow by heads when stands of pipe are removed, giving positive evidence of the fluid in the sand.

The sand tester is allowed to remain seated from 15 to 45 minutes depending on the condition of the sand. The complete test requires a round trip plus the 15 to 45 minutes it is allowed to remain seated and takes about 2 hours for a complete test, which is very small as compared to setting pipe and bailing out.

The sand tester has not found favour with operators in California owing to the liability of the formation to cave in, due to its incoherent nature, and 'freeze' the tester, resulting in an expensive fishing or side-tracking job. In this respect, the sand conditions in Burma are more like Californian conditions than those obtaining in the Mid-Continent, where the sand tester has been extensively used; but it is doubtful if the risks attending its use in Burma would be greater than those incurred by the current practice of making temporary isolations in cable-tool holes in order to carry out the same tests.

Use of cable-tool system for test wells.

The difficulty of obtaining accurate and detailed information of the formations encountered during drilling, and of their fluid contents, detracts from the suitability of the rotary method for drilling prospecting wells, and many American technologists still prefer to sink a cable-tool well in unproven territory. One 'wild cat' well I visited, situated over 100 miles from railway or metalled road in the sandy wastes of New Mexico, was drilled by rotary methods till the anticipated horizon for production was approached. The company then went to the expense of taking down the rotary drill derrick and hauling in a cable-tool outfit in order to secure an accurate log of the potentially productive horizons. This case demonstrates the distrust with which the technologists of that progressive company regard the use of rotary methods in prospecting wells. Had they considered any current adaptation of the rotary system capable of giving adequate information of the sand conditions they would certainly not have incurred the great expense of hauling in cable-tool equipment.

While the taking of cores, and possibly the use of the formation tester, have greatly enhanced the value of the rotary system in development work, in which the taking of cores should form part of the routine practice, the use of cable-tools for testing unproved

horizons is greatly to be preferred to any current adaptation of the rotary system.

Penetration of mud fluid.

The second disadvantage in the use of the rotary system, the contamination by mud fluid of low-pressure producing horizons, is one which has led to the control and restriction of the use of rotary drilling in the reserves of the Yenangyaung field of Burma. During the process of drilling through porous sands, part of the mud fluid enters into the pore spaces and other crevices. In a tight, consolidated sand the penetration of mud fluid is so slight as to require the microscope for its detection, but in very porous, loose sands mud fluid has been known to travel as far as 1,000 feet. In the reserves of Yenangyaung, the penetration of mud fluid in the upper depleted zones was sufficient to mud up producing wells in the neighbourhood, and in some instances production was never recovered. For this reason the use of the rotary system in these areas is permitted only under exceptional circumstances.

In a treatise on the subject of mud fluid penetration, Mr. R. E. Collom,[1] formerly Oil and Gas Supervisor of the State of California, states that the following factors control penetration—

(*a*) Nature of the openings or porosity of formations.
(*b*) Effective hydrostatic pressure of fluid on formations.
(*c*) Hydrostatic or rock pressure of native fluids in formations.
(*d*) Diameter of hole, filter area.
(*e*) Amount of depletion of oil or gas sands.
(*f*) Amount of pressure reduction in an oil sand brought about by pumping adjoining wells.
(*g*) Physical characteristics of mud fluid.
(*h*) Kind of native fluids—oil, gas or water in formations.

Mr. Collom further states 'It is probable that, as regards penetration, the physical nature of the mud fluid is as important a consideration as the porosity of underground formations.'

It is well known that the power of penetration into the formation of a mud fluid is reduced by the addition of certain substances. An outstanding example is hydraulic lime, the use of which has frequently been successful in restoring lost circulation (an extreme case of penetration) in Californian fields. It is possible that the use of lime or some other substance in muds used in rotary drilling

[1] Collom, R. E. 'Mud Fluid of Rotary Drilling, California Oil Fields', Vol. 8, No. 7, p. 24.

in Burma would so reduce the penetration as to eliminate the objection to their use in the reserves of the Yenangyaung field.

Low pressure completion.

An outstanding difference between Californian and Burmese rotary practice is that in California it is customary to complete wells by rotary drilling, whereas, in Burma, it is usual to drill wells down to the isolation point by this method and then to substitute cable-tools for drilling into the producing horizon. The reason for this practice in Burma, is the comparatively low pressure of the producing formation, a pressure that is insufficient to overcome the plastering effect and penetration of mud fluid. In general, the pressures encountered in Californian fields are sufficient to cause the well to flow and clean the formation in the neighbourhood of the well from mud fluid when the pressure on the sand is reduced by bailing out the column of fluid in the well. In some instances where the pressure is not sufficient to do this it is the practice of operators to use oil instead of mud fluid as the circulating medium when penetrating the productive horizon with rotary equipment. The Union Oil Company of California have carried this idea a step further. Their technologists consider that even when oil is used as the circulating medium, if the pressure on the formation exerted by the column of fluid in the well exceeds the formation pressure, fluid from the well enters the formation, carrying with it 'cuttings' which have a sealing effect on the sand. The technologists have, therefore, developed a system of restricted circulation, in which the pressure on the formation is reduced to approximately 500 lbs. per sq. inch, as compared with 1,500 lbs. per sq. inch when using a full column of oil to the surface or approximately 2,000 lbs. when using 70 lbs. mud. Circulation to the surface is abandoned when the productive horizon is approached, but, by means of a system of valves in the drill stem and a small air compressor at the surface, a limited volume of oil is circulated, in the lower portion of the hole only; this serves to cool the bit. It is necessary to carry down pipe during this process and also to run the bailer to remove the 'cuttings'; the amount of the latter, however, is reduced by the use of a core barrel, and it is claimed that the method results in more rapid drilling than with the cable-tool system. At the time of my visit this method of restricted circulation was still in its experimental stage, but had, so far, been used successfully on four wells in the Brea oilfield, where the initial production of each well was more than 100 per cent. greater than

that of wells drilled to the same sand by ordinary rotary methods. In one instance, a well which was drilled by ordinary circulating methods 'came in' at 60 barrels, but when the original hole was side-tracked from the isolation point, using this system of restricted circulation, the new hole 'came in' at 300 barrels. It appears possible that some modification of this method might be adapted to drilling with rotary methods in low pressure formations in Burma.

The third outstanding disadvantage of the rotary system, as at present operated, is the difficulty of drilling straight holes by this method. The table opposite, compiled by Mr. Anderson, the leading authority on the subject, shews that the average deviation from vertical of 163 rotary drill holes was 307·7 feet at a depth of 4,000 feet and 515·9 feet for 104 holes carried to a depth of 5,000 feet. Deviations of such magnitude not only greatly increase the difficulty of correlation from rotary drill hole data but are also conducive to excessive wear of the drill pipe and casing, and later of the pumping equipment.

Deviation of rotary drill holes.

The amount of deviation can be restricted to a certain extent by careful control of the weight on the bit during the process of drilling. Such control is facilitated by the use of the Hild and Halliburton differential drives, but even the most careful use of these devices has not been entirely successful in producing straight holes.

As regards the prevailing direction of deviation, there is a wealth of conflicting evidence; in some instances the tools travel down the dip, resulting in deviation of the hole in this direction; in other cases they travel in the opposite direction; and in yet other cases the direction of maximum deviation is along the strike. It is thought by many operators that the direction of deviation depends on the nature of the formation and on the degree of its inclination, but in one instance that was brought to my notice surveys of three adjacent wells, situated along the strike in a Californian field, shewed that the two outside wells went down the dip while the middle one went in the opposite direction. It is reasonable to assume that the field conditions in these instances were identical and it is, therefore, necessary to attribute the difference in the direction of deviation to differences in the mode of operation of the tools. This example would tend to indicate that more can be done by the driller to

DRIFT AND INCLINATION OF OIL WELLS.

Some data from underground surveys of 255 rotary drilled holes mainly in California—1,158,542 feet of hole and 13,150 individual survey readings.

No. of holes.	A. Depth in feet (measured depth).	B. Horizontal distance from mouth to bottom of hole. In feet. Maximum.	Minimum.	Average.	C. Inclination of hole from vertical in degrees and feet per 100 feet. Maximum.	Minimum.	Average.	D. Amount of drift from vertical. In feet. Maximum.	Minimum.	Average.
255	500	87	0	8·7	8° 20′ 14·5 ft. per 100	0° 00′	2° 0″ 3·8 ft. per 100	114	0·0	10·6
255	1,000	181	0	30·2	15° 30′ 26·7 ft. per 100	0° 00′	3° 05′ 5·4 ft. per 100	181	0·0	34·4
248	2,000	455	1	89·2	34° 15′ 56·3 ft. per 100	0° 10′ 0·3 ft. per 100	4° 05′ 7·1 ft. per 100	457	1·5	104·5
219	3,000	845	9	119·5	32° 15′ 53·4 ft. per 100	0° 30′ 0·9 ft. per 100	6° 42′ 11·7 ft. per 100	850	47·0	204·9
163	4,000	1,036	6	236·5	40° 15′ 64·6 ft. per 100	0° 30′ 0·9 ft. per 100	9° 00′ 15·6 ft. per 100	1,285	77·6	307·7
104	5,000	1,752	29	396·8	52° 00′ 78·8 ft. per 100	0° 30′ 0·9 ft. per 100	15° 44′ 27·2 ft. per 100	1,815	91·0	515·9
38	6,000	2,200	74	589·4	65° 15′ 90·8 ft. per 100	2° 30′ 4·4 ft. per 100	22° 25′ 38·1 ft. per 100	2,228	357·0	793·1

This Table, the surveys, the methods and apparatus employed are by Alexander Anderson, Mining and Petroleum Engineer, Fullerton, California.

Explanation of Terms.

'B.' Is the horizontal distance between a vertical line through the mouth of the hole and a vertical line to the hole at the listed depth.
'C.' Is the inclination from vertical at the listed depth.
'D.' Is the total drift from vertical down to the listed depth. In the case of a well drifting in the same direction from mouth to bottom 'B.' and 'D' would be equal.

control deviation in rotary drill holes, than has previously been realised.

RECOVERY.

The term *recovery* is used to denote the total amount of oil—expressed in terms of barrels, gallons, or tons—recovered from a well, lease, acre or any other unit; and since such a total depends on a large number of factors, as for example the original conditions in the reservoir, methods of production, and the like, it is usual and convenient to consider these factors under the heading of recovery. In dealing with the subject, it is necessary to remind ourselves that recovery is synonymous with total production and is distinct from and should not be confused with rate of production, often spoken of elliptically as production.

Production in the sense of rate of production of oil or gas, as the case may be, is expressed in terms of barrels or gallons (cubic feet in the case of gas), per day, month, year, or any other convenient period. Recovery is a function of rate of production but the relationship is a very complex one; so complex that some of its implications are at present imperfectly understood and it is essential to guard against the tendency to regard recovery as simply proportional to rate of production. It is obvious that a well that produces 10 barrels of oil per day for 1,000 days will have a smaller rate of production, but a greater recovery, than one that produces 20 barrels of oil for 100 days. There has been, and still is, however, a tendency, particularly among producers, to confuse the two and to regard any means of increasing rate of production as also increasing recovery.

Factors controlling recovery.

By a careful analysis of the production records of a well or lease over a protracted period it is usually possible to form at least an approximate estimate of the ultimate recovery from that well or lease, and it is, therefore, of the utmost importance that accurate and detailed production records should be kept.

The factors controlling recovery fall under two headings:—

(*a*) Natural conditions within the reservoir.

(*b*) Methods of drilling and production.

Over the former, the producer has no control, but a proper understanding of them is essential in order to determine the best methods of development and production. The latter are variable

at the will of the producer and are subject only to the limitations of current engineering practice and economic considerations, and it is with them that we are most intimately concerned.

The principal factors, as far as they are at present understood, falling under the first heading are:—

(1) The geological structure.
(2) The thickness, porosity, and permeability of the sand body or other reservoir.
(3) The physical properties of the oil, the most important of which are its specific gravity, viscosity, and surface tension.
(4) The pressure under which the oil and gas exist in the reservoir.
(5) The amount of gas dissolved in the oil, and in some instances the amount of free gas in the reservoir.
(6) The existence and mode of occurrence of water within the reservoir.

Of these, numbers 3, 4 and 5 are related — numbers 4 and 5 intimately so -- and are now almost universally believed to be of the greatest importance in the majority of fields. In other areas, number 6 is the predominant factor. There are substantial grounds for the belief that the oilfields of Burma belong to the former type, in which the pressure and the amount of dissolved gas are the most important natural factors affecting recovery; but many aspects of water encroachment, although of secondary importance, are by no means insignificant.

The principal factors under the second heading (*b*), those over which the producer exercises more or less complete control, are:—

(1) The location and spacing of wells.
(2) The methods of drilling and completion of wells.
(3) The methods of production.

Of production methods, by far the most important may be summed up under the general term pressure control. Just as the original pressure and the amount of dissolved gas within the reservoir are believed to be the most important natural factors affecting recovery, so are the proper control of pressure and the most efficient use of the original gas content of the reservoir (more particularly of that portion which is dissolved and occluded in the oil) believed to be the most important factors in production.

Since decisions as to the placing and spacing of wells, and also production methods, are affected by the question of pressure control it is expedient to discuss the principle underlying pressure control at this stage. Consideration of the production methods designed to accord with pressure control is deferred in order to preserve, as far as possible, a logical sequence.

Theoretical considerations underlying the control of gas-oil ratios.

Briefly, an oil 'pool' of the type with which we are dealing in Burma, consists of a sand body, the pore spaces of which are impregnated with oil and gas. In the majority of cases, and in every case in Burma, with possibly one exception, the strata in which these 'oil pools' are known to occur are folded into an anticline or elongated dome. Where there is continuity between the different portions of the sand body over a considerable area, it is almost universally found that there is a segregation of the fluid content of the reservoir according to its specific gravity; free gas, where it is present, being found in the top of the structure, followed by oil below, and the oil in turn followed by water down the flanks of the fold.

In addition to the free gas in the top of the structure a certain amount of gas is dissolved in the oil itself, the amount depending on the nature of the gas and of the oil and on the pressure under which they are associated in the reservoir. For an association of any one gas with any one oil, the amount of dissolved gas (temperature being constant) is proportional to the absolute pressure (Henry's Law). It follows, therefore, for reservoirs of this type in which there is free gas in the top of the structure, that the higher the pressure the greater the amount of dissolved gas. Another important result of this physical law is that when the pressure is released, gas comes out of solution. When a well is drilled into a closed reservoir, the pressure equilibrium is disturbed and gas is liberated from solution in the oil in amounts proportional to the pressure differential between the reservoir and the bottom of the well. As a further consequence of pressure reduction the gas expands and moves in the direction of lowest pressure, that is, to the well. In doing so the expanding gas bubbles carry oil with them to the well and it is this propulsive force of natural gas that is the most important factor in recovery. Other things being equal, therefore, the recovery from oil pools may be expected to be proportional to the amount of dissolved gas and

therefore to the pressure. In a series of experiments, conducted at the U. S. Bureau of Mines Experimental Station, Bartlesville, Oklahoma,[1] in which field conditions were simulated as closely as possible, this hypothesis received remarkable confirmation as will be seen from the following table :—

Percentage Recovery of Oil from Sand by Expulsive Force of Dissolved Gas for Various Initial Gas Pressures and for Different Rates of Recovery.

Initial pressure, lbs. per sq inch.	Solubility factor, cubic feet gas in 1 barrel oil.	Maximum total recovery. Per Cent.	Minimum total recovery. Per Cent.
25	4·77	9·4	9·4
50	9·54	12 5	11·7
75	14·22	15·0	13·2
100	18·98	17 0	14·5
150	30·32	20·3	16·5
200	37·75	23·4	18·1
300	56·70	28·0	20·5
400	75·40	31·1	22·6
500	94·32	33·8	24·2
600	113·07	36·1	25·7
700	132·26	38·1	27·0
800	151·02	40·0	28·0

As stated above, the pressure and the amount of dissolved gas in any particular reservoir are definite and limited and are natural conditions over which the producer has no control; but since the propulsive force of expanding gas is believed to be of the utmost importance in the production of oil, it is essential that this limited energy should be used in the most efficient manner. In other words,

[1] Van Mills, R. and others—'Oil Recovery Investigations of the Petroleum Experimental Station of the United States Bureau of Mines.' A. I. M. E. Technical Publication No. 144.

it is desirable that as little gas as possible be allowed to escape to the well without bringing with it its quota of oil, and the volume of gas per unit of oil produced may be regarded as an index of the efficiency of production. This ratio of the volume of gas to the volume of oil produced is known as the gas-oil ratio. The term has figured very largely in all the recent technical literature in the United States of America and it is no exaggeration to state that in the great majority of fields, the control of gas-oil ratios is now universally believed to be of paramount importance. This control is particularly important in the early stages of the productive life of a field or well, but it is necessary to guard against a too rigid adherence to this control in the later stages of the life of a field, when it is possible that other factors (such as gravity) and not the propulsive force of expanding gas, are predominant.

Mr. H. C. Miller[1] of the San Francisco office of the United States Bureau of Mines, has made a study of five Californian wells, originally large producers but now about to be abandoned, to determine the relation between the quantity of oil produced during the productive life of the wells and the volume of formation gas that accompanied the oil to the surface. The result of this study is shewn graphically in Plate 11. Curve A shows the relation between the percentage of the total oil that was ultimately recovered from the wells and the percentage of the total volume of gas (measured at atmospheric pressure) that reached the surface with the oil. In each case 100 per cent. equals the total production of oil, or gas during the life of the wells. The productive life of the five wells was about 12 years.

During the period of natural flow in the five wells, an average of 65 per cent. of the total gas that was produced during the life of the wells reached the surface, bringing with it but 45 per cent. of the total quantity of oil that was ultimately produced from the wells. In other words when natural flow ceased, there remained in the producing formations only 35 per cent. of the gas ultimately recovered. This percentage of gas expelled from the sands the 55 per cent. of the total recovered oil that was extracted by mechanical pumping methods.

Indicative as these figures are, of the inefficiency of the recovery of oil from reservoir sands by gas during the period of natural

[1] Personal communication.

flow, they do not depict the actual inefficiencies of recovery methods. Consideration must be given to the fact that only 20 to 40 per cent. of the total oil content of the sands is recovered by drilling operations. It should be noticed (curve D) that, on the basis of a 20 per cent. recovery, 65 per cent. of the gas from the reservoir sands (all of which came from a well during the period of natural flow) expelled only 9 per cent. of the total oil content of the sand.

These figures shew the need of conserving the energy contained in the gas associated with the oil, especially during the period of natural flow. If, by a change of methods of production, the volume of gas reaching the surface during the period of natural flow can be reduced, the length of the time that the well will flow naturally and the total ultimate recovery will be increased. Conserving gas underground, and maintaining proper gas pressures in wells, result in the recovery of the maximum amount of oil at least cost. An efficient method of production is, therefore, one that controls the volume of formation gas accompanying a barrel of oil to the surface. Such control should begin as soon as the well is brought in.

Having accepted the hypothesis that the control of gas-oil ratios, at least in the early stages of the field's history, is of paramount importance, it is now necessary to examine the effect on gas-oil ratios of the location and spacing of wells.

The effect of spacing on recovery.

There is very little published information on this subject and practically no concrete data are available, but the general consensus of opinion among American technologists is that the closer the spacing of wells the greater the recovery and, with few exceptions, the only limit they would impose on spacing is an economic one. I have examined all the available published references to the subject and have been permitted to consult unpublished reports on this question in the archives of several large producing companies. With few exceptions, they purport to show that the closer the spacing the greater the recovery, but in no instance do I consider that the data unequivocally warrant this interpretation. Furthermore, after exhaustive discussion of this question with the exponents of the opposite view, I am still of the opinion that there are theoretical grounds for the belief that there is a limit beyond which close spacing is not only uneconomic but also results in lower recovery. The reverse view depends entirely

on the principle that it requires more energy to move a unit of oil two feet than it does to move it one foot, and that the closer the wells, therefore, the less is the energy required to produce the oil. This argument is undeniable, and if in such circumstances all the available energy were actually used in bringing oil to the well, the case for close spacing would be complete. It has been shewn, however, (see page 404) that in the early stages of the life of a well there is great wastage of gas energy. It will be shewn later that this wastage is largely due to a too rapid relief of pressure, whereby gas is allowed to reach the well without bringing with it its quota of oil, known as 'by-passing' of the gas. Every additional well in excess of the number required efficiently to drain the sand, will result in a still more rapid reduction of pressure and the early intersection of drainage cones surrounding the wells will constitute an additional source of dissipation of energy. By restricting the number of wells, the amount of 'by-passing' of the gas will be substantially reduced and the pressure reduction in the reservoir can be more easily controlled. It is possible that the conservation of gas energy thus effected will outweigh the extra energy involved in propelling the oil for a greater distance and so result in greater ultimate recovery. This view is not entirely without experimental confirmation. In a series of experiments conducted on a laboratory scale, Professor Lester C. Uren[1] obtained the following data, indicating that while one well was insufficient for efficient drainage, every additional well in excess of two resulted in lower recovery.

Results of Pressure-drainage Tank Experiments to Determine Influence of Well Spacing on Ultimate Recovery.

No. of wells.	Total recovery of oil cu. cm.	Percentage recovery.
1	103,705	25·7
2	117,100	29·0
3	105,700	26·1
4	102,500	25·4
5	101,100	25·0
6	99,300	24·6

[1] Uren, L. C.—'The Gas Factor as a Measure of Oil Production Efficiency.' 'Petroleum Development and Technology in 1927,' p. 153.

If these results may be accepted as a reliable index of the performance of wells under field conditions, it follows that in every field there will be some limit beyond which closer spacing will be to the detriment of ultimate recovery. In the present stage of our knowledge it is impossible to say what that limit is and it will vary in every instance, as it depends on the original pressure in the reservoir, the porosity and permeability of the sand, and other physical factors. The most efficient spacing, therefore, can only be determined by experiment. The subject, however, is of more than academic interest, particularly in Burma, where, in the reserves of Twingon and Beme we have the unprecedentedly close spacing of 60 feet.

Effect of location and rate of development on recovery.

Closely related to the question of spacing, or the distance between neighbouring wells, are the location, or position of wells on the structure, and the rate of development.

It is usually found that wells situated near the crest of a structure, have higher gas-oil ratios than those lower down the flank. This difference is due to two causes; the greater facility with which gas migrates up the structure (and therefore the tendency of wells situated near the crest to drain gas from the lower portion of the structure) and the proximity of the crestal area of free gas from which gas escapes to adjacent wells. Although this free gas is not so important a factor in the production of oil as that which is dissolved and occluded in the oil itself, its conservation as a measure of pressure maintenance is important. Any excessive drainage from this area, either by gas wells located on the crest itself, or by oil wells situated near the crest, will result in a general diminution of pressure throughout the structure and so result in a lower recovery of oil.

In the Ventura and Dominguez fields of California, in which attempts are being made, under co-operative agreements among the operators, to control gas-oil ratios, two of the major companies have actually shut in and sacrificed production from high gas-oil ratio wells situated high on the structure. These wells were drilled before the importance of the above considerations were fully realised, but the occurrence of such wells with high gas-oil ratios near the crest of the structure, and the beneficial results, on the aggregate gas-oil ratio of the field, of closing them in, are sufficient to warrant a restriction of drilling on the crestal portions of a

structure in future development programmes. Such restriction of drilling on the crest of a structure, or the extreme measure of shutting-in high gas-oil ratio wells that have already been drilled there, must, however, be accompanied by proper pressure control of producing wells surrounding the protected area. Otherwise, the gas from this protected region will migrate to such producing wells and be dissipated there.

With the exception of this restriction of drilling on the crestal portions of a structure, for the reason stated above, American technologists now believe that rapid and uniform development results in the greatest recovery. If development is not rapid and uniform the drainage of gas from undrilled areas by wells completed early in adjacent portions of the structure, results in high gas-oil ratios in the completed wells. This position is particularly acute where the congestion of wells in the drilled portion is excessive, as is frequently the case where line fights take place between rival companies.

In a recent report on the Powel field, Navarro County, Texas, Mr. H. B. Hill[1] of the United States Bureau of Mines comments on this subject as follows:—

> 'The policy of drilling line wells only, during the early period of development reduces the ultimate recovery from the tract and the recovery per acre........ In properties developed in this manner, water is quite likely to follow the areas of greatest depletion and consequently to trap large quantities of oil in underdeveloped portions of the tract.'

As stated above, the evils consequent upon close drilling of wells can be reduced by proper pressure control of the completed wells, but it is doubtful if they can be entirely eliminated, particularly under competitive conditions where close co-operation of the operators is essential for pressure control. In places where such co-operation is obtainable, the interests, both of the competing companies, and also of the state, would be better served by an agreement to pursue a rational drilling policy.

Production efficiency.

Having discussed the most important aspects of development, production methods, in relation to their efficiency in yielding the greatest ultimate recovery, remain to be considered.

[1] United States Bureau of Mines Bulletin No. 284, pp. 104-5.

Methods of increasing oil production efficiency fall under two headings:—

(1) The control of individual wells or groups of wells in such a manner as to reduce their gas-oil ratios and to control the influx of water.

(2) Secondary methods of recovery such as production under vacuum and the re-introduction of gas into the oil bearing formation, for the purpose of maintaining or restoring pressure.

It is believed that with ordinary flowing and pumping methods, a comparatively small proportion of the total oil content of the sand is recovered. The estimates of various technologists, under varying field conditions, range from 20 to 40 per cent., so that a large proportion of the total oil content of the reservoir remains in the ground. Technologists now believe, that by proper development programmes, together with efficient control of gas production and pressure, the percentage of oil recovered can be materially increased and, furthermore, that the recovery from depleted fields can be still further increased by the adoption of some repressuring system.

Theoretical considerations underlying the control of pressure.

It cannot be too often repeated that it is the propulsive force of natural gas that is now believed to be the most important factor in recovery. Under ideal conditions each unit of gas is capable of doing a certain amount of work in bringing oil to the well, the work done depending on the amount of expansion of the gas and therefore on the differential pressure between the formation and the well. Gas, however, is a more mobile fluid than oil and there is, therefore, a great tendency for it to escape to the well without bringing with it its quota of oil. This phenomenon is known as 'by-passing' or 'slippage'. In general, the greater its velocity of flow the greater will be the tendency of the gas to pass to the well without bearing its quota of oil. Now, other factors being constant, both the amount of gas liberated from solution in the oil and the amount of its expansion, and therefore its velocity of flow, will be proportional to the pressure differential between the formation and the well. It will readily be seen, therefore, that both the power of the gas to perform work in bringing oil to the well and its tendency to escape without doing

this work, are dependent on the same factor, differential pressure. For each reservoir, therefore, for each well in the reservoir, and even for each stage in the life of the individual wells, there will be some critical pressure at which the most efficient balance between these two factors will be reached. If the differential pressure is too small, the energy of gas expansion will be insufficient to bring oil to the well; if the differential pressure is too great, gas will escape to the well without bringing with it a sufficient quantity of oil. Clearly the most efficient balance between these two factors is reached at that pressure differential at which each unit of gas brings with it to the well the greatest quantity of oil, in other words, that difference of pressure at which the gas-oil ratio is the smallest. The problem of the engineer and technologist, therefore, is to determine by experimentation on individual wells the operating pressure at which they have the lowest gas-oil ratio.

Effect of pressure control on water encroachment.

The above is a discussion of the theoretical considerations underlying the principle of pressure control of producing wells, particularly in relation to gas conservation. Before turning to the consideration of its practical application we may remind ourselves of its beneficial results in the control of water encroachment. Where wells are allowed to flow freely without proper attention to pressure control, the rapid diminution of pressure in the neighbourhood of the wells causes the rapid advancement of edge water, irregular tongues of which are drawn up towards the region of lower pressure. The irregular nature of this encroachment causes large bodies of oil to be entrapped and renders such oil recoverable only by the expensive and usually uneconomic method of drilling additional wells, a policy which few companies are prepared to pursue after the encroachment of edge water is known to have commenced. This aspect of the subject has been well brought out in the recent development of the West Texas fields where wells come in with high initial productions but rapidly become affected by water unless production is effected under substantial back pressure. In the course of a visit to each of the newer fields in West Texas, a great number of production curves illustrating the relationship of back pressure to control of water encroachment were studied. The majority of these curves were of a confidential nature, but that comprising Plate 12, taken from

published records,[1] is typical of a great number of curves that have been compiled from data obtained in this area.

Miller has shewn (see page 404) the importance of the control of back pressure early in the life of a well, and it is in accord with general experience that far more can be done to conserve formation gas in the early flowing period of a well's life than at any other time. Speaking on the subject at a meeting of the American Petroleum Institute, held in Los Angeles on the 21st of September, 1928, Swigart,[2] one of the pioneers of gas conservation in the States, said:—

Pressure control of flowing wells.

'Back pressure control has not been successful in securing moderate gas oil ratios for all wells at Ventura because as has been learned from experience, wells can be controlled more successfully if taken in hand shortly after completion than if allowed to produce at rapid rates for several months or years. Many Ventura wells were old when the control methods were first applied. In general, the Shell Company has been able to maintain gas oil ratios of new wells at fairly constant levels and even to lower the gas oil ratios of a number of wells. In experimenting with old wells which have attained high ratios, it was found difficult to lower those ratios and in most cases wells of this kind have finally been shut in completely to save gas.'

Dealing with the results of back pressure control in the Ventura field, Swigart[3] also states.–

'It is estimated that the total field gas oil ratio if all wells were allowed to produce at normal rates, would be approximately 4,950 cubic feet per barrel at the present time. The present field ratio is about 3,780 cubic feet per barrel indicating a saving of 1,170 cubic feet of gas for every barrel of oil produced.

To give some idea of the possible value of this decrease in gas-oil ratio, assume that the saved gas will some day produce oil at the rate of 4,000 cubic feet per barrel. This would mean that for every barrel being produced under present methods, an extra 0·29 of a barrel will be produced ultimately, or stated differently, with a present total field oil production of approximately 50,000 barrels per day, ultimate production is being increased at the rate of 14,640 barrels per day by the present methods of gas conservation. Even if the gas saved were only one-half as effective as at present in driving oil from the sand the daily rate of increase in ultimate recovery would be 7,530 barrels per day which is equivalent to an increase in recoverable oil reserves of 15 per cent.'

These results in the control of gas oil ratios of flowing wells (accomplished in the Ventura field), constitute a remarkable vindica-

[1] Vance, H.—'Development and Production Methods in West Texas Fields,' Bulletin No. 202 of the American Petroleum Institute, p. 113.

[2] Swigart, T. E.—'Proration in the Ventura Field,' paper presented before a District Meeting of the Division of Development and Production Engineering of the American Petroleum Institute, at Los Angeles, California, September, the 21st, 1928.

[3] Swigart, T. E.—*op. cit.*

tion of the theoretical expectations of the benefits of pressure control of such wells. The most successful method employed in this field is the use of 'flow beans' which increase the effective back pressure on the sand by reducing the orifice of flow. By this method, pressures as high as 1,000 to 1,200 lbs. per square inch have been held on Ventura flowing wells with the beneficial results cited above.

Another method of controlling flowing wells is to allow them to flow through tubing, when the back pressure can be controlled by altering the diameter and depth of tubing. In Ventura this method has not been so successful as 'beaning', as it is not practicable to change the depth or diameter of the tubing in order to 'kill' high pressure wells. In the Salt Creek field, however, where pressures are not so high, allowing the flow to occur through tubing proved the most successful method of control. As the result of considerable work in this field, Mr. K. B. Nowels[1] of the United States Bureau of Mines, was able to draw the following conclusions :—

'Casing flow and its control by gate valves usually gave inefficient results in gas-oil ratios, with a few exceptions.

Casing flow of a certain percentage of the total open flow was easier of control by flow nipples or beans and gave somewhat better gas-oil ratios than did gate valve control.

Producing a well through tubing was generally the best arrangement, thereby obtaining increase of efficiency; although there were exceptions, however, it is believed some tubing arrangement would have given the desired result.'

Pressure control of gas-lift wells.

In a flowing well, the gas that exists in the formation in association with the oil performs two functions: the first in bringing oil to the well; the second in lifting it to the surface. Of these, the former is the more important, as, when once the oil has reached the well, the energy required to elevate it to the surface can readily be supplied from extraneous sources. The energy required to bring the oil to the well can by no means be so readily replaced. In the later stages of the life of a well, when the diminution of pressure and the greater distance through which the oil has to travel to the well result in the greater part of the energy of expanding gas being required to bring the oil to the well, the well

[1] Nowels, K. B.—'Some Methods of Producing Flowing Wells in the Salt Creek Field and Their Effect on Gas-Oil Ratios', United States Bureau of Mines Report of Investigation No. 2833, p. 5.

ceases to flow and the oil has to be brought to the surface by mechanical means. It follows, however, that if the energy required to lift the oil to the surface can be extraneously supplied at some earlier period in the life of a well, the energy of the formation gas, which would otherwise have been absorbed in doing this work, will, if properly controlled, be available for the purpose of bringing additional quantities of oil to the well. This conservation of energy is an important function of the gas-lift method of production, in which gas is pumped down the well to bring the oil to the surface, but it is a function that is frequently overlooked in view of the more general application of the method as an alternative to pumping as a means of bringing to the surface the oil from wells which have already ceased to flow. There is probably no other aspect of modern production methods in America, on which the opinions of field men are so divergent, as the efficiency of the gas lift method to perform this latter function. In this connection, the term efficiency is used solely with reference to the effects, beneficial or otherwise, of the gas-lift method on ultimate recovery. This divergence of opinion is undoubtedly due to the widely different methods of operating the gas-lift process in different areas. Although there is such divergence of opinion among field men, who are familiar only with the results of the method in their own particular area, among technologists and engineers who have greater opportunities of observing its operation under many different conditions in a great number of fields, it is almost universally believed that where the gas-lift method is properly used, as a means of pressure control instead of as a means of increasing daily production, use of the process has been an important factor in contributing to greater recovery. This difference in the method of handling the gas-lift process in wells and in the results on ultimate recovery, is well brought out in the following instances, quoted in a report published by the California Chamber of Mines and Oil [1] from which the following is taken :—

'Experience has shewn that control of the gas-oil ratio by regulating the effective back pressure on gas lift wells is fully as important as controlling the gas-oil ratio in natural flowing wells. Many operators have thought that the successful operation of gas-lift wells consisted in flowing them in such a manner as to obtain the greatest possible present daily oil production. Records of a number of wells show that when the gas-lift is applied without regard to the degree

[1] 'How to Increase Oil Recovery and Conserve Gas in the field ', p. 4.

of back pressure necessary for efficient oil recovery and only for the purpose of obtaining a large present increase in oil production, the results are usually a large increase in gas-oil ratio and a rapid decline in oil production.'

Plate 13. Fig. 1. 'is a segment of a daily production graph of a well in the Brea Field, California, which was flowing naturally against a one-inch bean until April 8th, 1927. Because the natural flow became erratic, tubing was lowered and the well flowed through casing with the gas-lift. The back pressure on the oil sand was decreased from over 200 lbs. per square inch to less than 140 lbs. per square inch. The oil production of the well was practically doubled for a week or so. However, the gas-oil ratio increased from 3,300 to 4,400 cubic feet per barrel and a decline in oil production set in at a very rapid rate, as may be seen from' Plate 13, Fig. 1.

'Compare this result with that obtained in a well in the Dominguez field, illustrated in' Plate 13. Fig. 2. 'This latter well was flowing naturally at the rate of 580 barrels per day in December 1926, but in January and February 1927, declined at an abnormal rate, indicating the need for gas-lift assistance, two and one-half inch tubing which had been hanging at 3,734 feet was removed and 4,207 feet of 3-inch tubing was run on February 13th, 1927. The well was put on gas-lift, the flow being directed through the tubing. Oil production increased at once to 750 barrels per day, which was an increase almost as large, proportionally as that obtained in the well shown in' Plate 13. Fig. 1. 'In contrast with the results obtained with the Brea well, the oil production of this Dominguez well continued at this high level for a period of over two months and then declined very slowly. Accompanying this change in flowing methods was a decrease in the gas-oil ratio as shown in' Fig. 2. 'This well illustrates the beneficial effects that may be obtained when flowing with gas-lift, provided thought is given to the control of back pressure on the oil sand. It is recommended that operators using the gas-lift, experiment with their wells in order to obtain the lowest possible gas-oil ratio. Although this may result in a slightly lower initial daily production with the gas-lift than could be obtained by a flowing well without restraint, the small initial loss will be exceeded by the sustained production of the well later on. Different tubing depths or the use of different sized tubing, as well as the use of trap pressure, of flow beans, or of variations in volume of circulated gas, afford means of controlling gas-oil ratios in gas-lift wells.'

Pressure control of pumping wells.

The extent to which back pressure can be applied to wells that require pumping depends on the degree of pressure depletion in the reservoir, and therefore on the age of the wells and the extent to which proper pressure control has been applied to them in the early producing years of their life. There are sufficient data available, however, to show that back pressure can be applied to wells that have to be pumped with beneficial results particularly in the earlier

stages. Writing on this subject in 1924 Swigart [1] and Bopp state :—

'Fairly high back pressures can be held on many pumping wells without cutting down their oil production and back pressures (gauge pressure *plus* fluid pressure) that approach closely the potential rock pressure of the reservoir can be held on some wells at a sacrifice of only small percentages of their present daily productions. Back pressures that seem most effective in increasing the efficiency of oil recovery by cutting down the number of cubic feet of gas per barrel of oil are those that affect the present daily oil production noticeably. To a certain limit, the higher the back pressure the higher the efficiency of production ; that is, the reduction in cubic feet of gas per barrel of oil becomes larger with every increase in pressure. However, if the differential pressure becomes so small that the oil production is cut 50 per cent. or more the efficiency of recovery may be less than at somewhat smaller back pressures (causing larger differentials), which permit a larger daily production of oil.'

More recently, in their report on 'How to Increase Oil Recovery and Conserve Gas in the Field', [2] a committee of California operators wrote as follows :—

'There are several thousand pumping wells in the state of California which together produce a large quantity of natural gas. With the exception of a few wells that have been subjected to experimental work, these pumping wells produce without any attempt being made to control their gas production. However, the experimental work which has been carried on indicates that many times very substantial reductions in gas production can be made by proper control of back pressures, and frequently this control can be applied without serious loss in present daily oil production, and with a resultant arrested decline which will be reflected in increased oil recovery.

Back pressure on a pumping well can be regulated either by means of a tight casing head making possible the holding of gas pressure on the casing, or by means of adjusting the tubing depth. The tubing depth method of controlling gas-oil ratios may be effective, but is more difficult to apply than the holding of gas pressure on the casing, because changing tubing depth does not permit the operator to know the exact amount of change in back pressure on the sands. Also, every change of back pressure by this method involves removing the well-head fittings and actually raising or lowering the tubing. Adjustment of back pressure by means of gas pressure in the casing may be obtained simply through the operation of a valve or the use of a flow bean on the blow-off-line from the casinghead. A pressure gauge on the casing gives a direct measurement of the change in back pressure.

The holding of gas pressure on the casinghead frequently causes trouble through gas-locking of the pumping valves, a difficulty which, unless it is detected and overcome, may result in abnormally low oil production, because the pump will

[1] Swigart, T. E. and Bopp, C. R.—'Experiments in the use of Back Pressures on Oil Wells', United States Bureau of Mines Technical paper No. 322, pp. 58 and 59.

[2] *Op. cit.*, pp. 5 and 6.

not pump down the fluid that has entered the well. This causes low daily oil production because of the failure of the pump to lift steadily and because the fluid level will rise and exert a greater back pressure on the sands than that indicated by the pressure gauge on the casing. Experienced production men readily detect gas-locking and correct it by means of gas anchors, by spacing the pump valves, and by other measures. However, unless this gas-locking is detected and corrected, low daily oil production may lead to erroneous conclusions regarding the actual potential production of the well against a given back pressure.'

Plate 14 'is the daily production graph for a pumping well in the Dominguez field that had an extremely high gas-oil ratio. When pumping with atmospheric pressure on the casing, the well had a daily production of 45 barrels of oil and 500,000 cubic feet of gas. By experimenting with different casing pressures, as shown on the graph the investigators found that by holding 40 pounds per square inch pressure on the casing it was possible to produce 50 barrels per day of oil with only 450,000 cubic feet per day of gas. This reduced the gas-oil ratio from approximately 11,000 cubic feet per barrel to about 8,700 cubic feet per barrel.

The adjustment of back pressure was obtained by using a small bean in the casinghead to bleed the gas to the desired pressure. The well, being very gaseous, gave considerable trouble at first through gas locks in the pump, but this was overcome by the use of a good gas anchor and a change in tubing depth.

Application of gas-oil ratio control to a large group of pumping wells would undoubtedly result in a greatly increased ultimate oil production and a substantial reduction in gas production and, therefore, gas surplus. It is thought that this field offers exceptional opportunity to the operator who is anxious to increase his ultimate revenue.'

With regard to the method of control of back pressure on wells that require pumping, there are other disadvantages inherent in the tubing depth method not mentioned in the above quotation. This method depends on the extent to which the fluid level is allowed to rise in the well; by raising the tubing the fluid level is allowed to rise to the same extent, but, in the case of wells which are producing water as well as oil this raising of the tubing is detrimental, as, owing to its higher specific gravity, the water remains at the bottom of the well while the oil rises above it. By reducing the depth of the tubing in such a well a column of water is allowed to stand on the sand. In their Cook and Turberville 'pools' (Texas), the Marland and Rosier Pendleton Oil Companies have, however, developed a method of control of back pressure by means of fluid levels in which the difficulty is overcome. The wells in these fields are pumped by 'pumping jacks' activated by a central engine, but, by means of a device known as a *rod-line multiplier*, the length of the stroke on each well is so regulated that the desired quantity of fluid is pumped. In this way the wells are continuously pumped

from the bottom so that all the water produced is pumped off, but by restricting the capacity of the pumps, a column of oil is allowed to build itself up in the well; the hydrostatic pressure of the column being the amount of back pressure on the well. In practice it is not necessary to know what that back pressure is; it is sufficient so to adjust the pump capacity that oil is obtained from the well and the lowest gas-oil ratio is maintained. The method of operation is very inexpensive to instal as the device used to control the length of stroke is such as can be made by any field carpenter, and once installed the length of the stroke can be adjusted merely by disconnecting the shackle line to the well and attaching it at a different height on the multiplier.

Secondary methods of recovery.

It will be realised that in all pressure control it will be necessary continually to reduce the back pressure to correspond to the pressure decline in the reservoir, in order to maintain the pressure differential essential for production. This process will ultimately bring us to the stage when the well ceases to yield economic production at atmospheric pressure. It will then be necessary to resort to some secondary method of recovery, of which, the two most important at the present time are production under vacuum and repressuring. Other secondary methods of recovery are flooding and mining. Of these the former is thought to be inappropriate to conditions in the major fields of Burma, while mining for oil forms the subject of a separate investigation.

Fundamentally, both production under vacuum and by repressuring depend upon the same principle; the maintenance of the pressure differential between the formation and the well. When the formation pressure has declined to the point where it is so near to atmospheric pressure that oil ceases to flow to the well, production can be stimulated either by holding some pressure less than atmospheric on the well or by restoring the formation pressure by the reintroduction of gas or air under pressure.

In other respects, the effects of the two methods are widely divergent, but before dealing with these differences and comparing the relative merits of the two processes it is advisable to remove a misconception which has existed in the discussion of the vacuum question. Many of its critics have affected to see in the vacuum method entirely new and unprecedented evils. The use of vacuum, they say, increases gas-oil ratios and is therefore detrimental to

ultimate recovery. If by holding any pressure less than atmospheric at the well head, the differential pressure between the formation and the well is greater than that which is necessary for efficient production, the imposition of this negative pressure, or vacuum as it is popularly called, is undoubtedly harmful, but this is no new evil. It is no more harmful than holding a correspondingly great differential pressure on the well at any other stage in its existence, far less so, in fact, than if excessive pressure differentials are permitted in the early life of the well. That a high pressure differential is less harmful during late stages in the life of a well than in early stages is due to two causes—the greater response to pressure control of which wells are capable in their early stages and their failure to respond to pressure control later (see page 411) if allowed to flow freely in their early life, and the increasingly important function of gravity as a factor in production in the later stages of the field's history.

A general discussion of the use of vacuum is of little significance; the questions that producers have to decide are :—

(1) Has the reservoir pressure declined to the point where it is necessary to hold a pressure less than atmospheric at the well head in order to promote the most efficient production ? and

(2) Is the use of vacuum the best method of secondary recovery available ?

Apart from its function in bringing oil to the well, the dissolved gas in a reservoir has certain physical effects on the oil itself. The most important of these are its effect on the specific gravity, viscosity, and surface tension of the oil, all of which are lowered by the solution of gas in the oil. As has been stated above, other factors being constant, the amount of dissolved gas is proportional to the absolute pressure, so that reduction of pressure, by allowing gas to come out of solution, tends to increase the specific gravity, surface tension, and viscosity of the oil, thereby increasing its inertia in the sand. These effects have not been mentioned earlier as their importance so far as production of oil is concerned, although at the present time imperfectly understood, is believed to be much less than that of the primary function of gas in bringing oil to the well. It must be remembered, however, that these effects do

not commence only when vacuum is applied. for the cause of these effects acts continuously throughout the producing life of the field, and the fact that such effects are produced constitutes yet another, although possibly a minor, argument for proper pressure control.

In addition to the increase in the specific gravity, viscosity, and surface tension of the oil, due to the liberation of gas from solution, diminution of pressure raises these values in yet another way. Crude oil consists of a series of hydrocarbons that are liquid at the temperature and pressures at which they exist in the reservoir, but of which the lower members are capable of becoming gases by reduction of pressure. The removal of these lighter constituents from the oil, by the reduction of pressure, also increases the specific gravity, viscosity, and surface tension of the oil remaining in the reservoir; but, unlike the escape of gas from solution, this denudation of the oil of its lighter constituents by evaporation is not proportional to absolute pressure, although it is greater at low than at high pressures.

These aspects are not without significance when one is considering the relative merits of the use of vacuum and of repressuring as secondary methods of recovery. Under vacuum, the increase in specific gravity, viscosity, and surface tension of the oil that has taken place throughout the producing life of the field continues, and is further enhanced by evaporation of the lighter constituents of the crude oil; whereas by repressuring (in which process gas or air is returned to the sand under pressure) not only is this increase arrested, but as a result of pressure restoration additional quantities of gas are dissolved in the oil, resulting in lowering the specific gravity, viscosity, and surface tension, and thereby *decreasing* instead of increasing the inertia of the oil in the sand.

Another advantage of repressuring over the use of vacuum, is the greater differential pressure between the sand and the well that can be maintained by the latter method. By the vacuum method, when once the reservoir pressure has declined to atmospheric, the maximum differential pressure that can be held between the formation and the well is 14·7 lbs. per square inch, corresponding to 30 inches of mercury, whereas the differential pressure that can be built up by repressuring is limited only by the capacity of the plant installed. In this connection, Mr. C. E. Beecher,[1] formerly of

[1] Beecher, C. E. 'Petroleum Development and Technology in 1926', p. 171.

the United States Bureau of Mines, estimates that for the money spent on a vacuum plant capable of holding a differential pressure of 14 lbs. per square inch, a pressure plant could be built and operated capable of holding a differential pressure of 150—250 lbs. per square inch.

The theoretical expectations of the superiority of repressuring to the use of vacuum are abundantly justified by the results obtained in actual field practice, and repressuring is now believed by American technologists to be the best secondary method of recovery in the majority of fields. The application of pressure was studied under a wide range of conditions in Oklahoma, Wyoming, California, and Texas; in all these places the application of pressure was found to result in astonishing increases in recovery. Before turning to the possibilities of the successful application of this method in the oil fields of Burma, a few concrete examples of results obtained in American fields are appended.

Results of repressuring in the Harmel Pool, Archer County, Texas.

This field was discovered in October, 1924 and drilling was carried to the economic limit in 1926. The depth and thickness of the sand are 1,340 and 12 feet, respectively. The initial average production per well was 70 barrels per day but the production had declined to 5 barrels per well by April, 1928. Repressuring was commenced by the Marland Oil Co., and its associates in February, 1926 using air as a repressuring medium. Through five wells 1,120,000 cubic feet of air per month were injected and production taken from 39 wells, the operating pressure on the injection wells being 35 lbs. per square inch. The immediate result was a flattening of the decline curve and a diminution in the water production. The introduction of air was continued until the gas at the casing-head of the producing wells contained as much as 65 per cent. of air in some cases, when it was decided to discontinue the use of air and substitute wet gas. This change was followed by a slight decline due to the fact that the volume of gas circulated was not equal to the volume of air previously injected. The quantity of gas, however, gradually increased and the net increase in oil recovery attributed to repressuring operations up to May, 1928 is estimated at 328,500 barrels; the production per well at that time being 13 barrels as compared with 5 barrels per well in the portions of the field in which renewal of pressure was not carried out. The production graph of this property is shown on Plate 15.

The Wiser Oil Company are employing dry gas in many properties, operating at pressures ranging from 40—275 lbs. per square inch. In one instance only have they been unsuccessful and in that instance a pressure of 250 lbs. was insufficient to force gas into the formation and, this being the limit of the capacity of the plant, the attempt was abandoned in view of the cost high of installing a more powerful plant and of the present low price of oil. In other properties the actual increase in production as a result of similar operations has varied in the individual wells. Some have scarcely been affected while others have yielded as much as 1,000 per cent. of their previous production. The production of one well had increased from one quarter barrel to 25 barrels per day, the production from other wells in the same property having increased from a quarter to 5 or 6 barrels.

Results of the Wiser Oil Company's repressuring in Bartlesville sand properties.

This Company is now also adopting the practice of repressuring on properties which had previously been under vacuum. In one instance a property producing from the Bartlesville sand had been under vacuum for 15 years. The vacuum was then taken off and repressuring adopted, 30,000 cubic feet of gas per day being injected through two pressure wells at a pressure of 145 lbs. per square inch. The production of the 13 producing wells rose in eight months from an average of 4·8 barrels per well to 13 barrels per well and is now (July, 1928) as high as 20 barrels. The cost of operating the pressure plant on this property is not appreciably greater than that of operating the vacuum plant, while the operating cost per barrel of oil recovered is very much reduced.

On another property the wells were held under 27 inches of vacuum in 1925, at the end of that year vacuum was replaced by pressure. During the vacuum period in 1925 the daily average production of the lease was 123 barrels. Commencing in November, 1925 a gas-air mixture consisting of 60 per cent. gas and 40 per cent. air was injected through 70 pressure wells at pressures approximating to 125 lbs. per square inch. In one year the average daily production of the lease had risen to 347 barrels and in May, 1928 was still on the upward trend at 480 barrels. The production graph and other particulars relating to this property for the period January, 1925 to December, 1927 are given in Plate 16.

In discussing these two properties the local manager of the Wiser Oil Company, expressed the opinion that the use of vacuum

had contributed to a much greater recovery than would have been obtained by production at pressures in excess of atmospheric, but was furthermore of the opinion that the present repressuring projects would result in a much greater enhancement of recovery than that attributed to the use of vacuum.

Results of repressuring in the Williams Pool, Callahan County, Texas.[1]

In the Williams Pool field of 172 acres, 69 producing wells each having a small initial production were completed at an average depth of 280 feet. The average thickness of the sand was originally recorded in the drilling logs as 16 feet, but core drilling and recent five-spot completions indicate a more or less broken, lenticular sand body, consisting of shale partings and sand members of varying texture and saturation. The thickness of the oil-bearing sand probably averages 10 feet. All the wells originally selected for returning gas to the formation on this lease were later replaced by wells drilled specially for the purpose of forcing air into the oil sand and it was not till this was done that any appreciable increase in production was obtained. The pool was discovered in 1923 and repressuring started in June, 1926. In April, 1928 there were 61 producing wells and 9 input wells through which approximately 550,000 cubic feet of air were delivered daily to the sand at pressures varying from 47 to 130 lbs. per square inch. The predicted normal daily production for the pool, obtained by extending the decline curve, was computed in April, 1928 at 92 barrels. The actual production at that time was 180 barrels, being an increase of 96 per cent. in the daily production, after 22 months during which pressure was applied, as compared with results otherwise anticipated.

Results of gas storage in the Dominguez field, California.

Twenty million cubic feet of gas per day are now being returned to the oil-bearing formation in the Dominguez field by co-operative agreement between the Union and Shell Companies. Although this agreement is primarily to secure gas storage, and the effects on the present production of the field are obscured by the large increase in operating pressures on the producing wells, the effects on the restoration of pressure in the field are of considerable interest.

[1] Hill, H. B., United States Bureau of Mines, Dallas—personal communication from an as yet unpublished manuscript.

The combined compressor equipment of the two companies consists of nine machines having a total capacity of 22,000,000 cubic feet. All the compressors have a maximum working pressure of 800 lbs. per square inch. The actual injection pressure at the 10 input wells varies from 450 to 750 lbs. per square inch depending on the position of the well on the structure and the degree of depletion of the original reservoir pressure.

Speaking at a meeting of the American Petroleum Institute, held at Los Angeles on September the 21st, of the effects of this co-operative project on the producing wells of the field, Mr. E. W. Masters of the Shell Company said: –

'Gas storage has had a pronounced effect on the majority of producing wells of the field and the tendency of gas-lift wells to flow naturally after gas injection was started has been especially noticeable. Thirty-seven wells were being flowed by gas-lift before the test began and required a total daily dry gas circulation of 9,220,000 cubic feet. On September 1st, the total number of wells on gas-lift had been reduced to 19, so that 18 wells are now flowing naturally again without the assistance of dry gas circulation. The volume of dry gas circulation has also been reduced to 4,268,000 cubic feet by the latter date, representing a pronounced saving in operating costs. Moreover, observations indicate that several of the remaining gas-lift wells will soon be flowing naturally and this will further reduce operating costs. ....'

The table below

'lists influenced wells and gives an idea of the effect to date caused by the injection of gas and measures taken to prevent increasing daily gas production. Before the introduction of gas, pressure in the producing sands had become so low that all gas-lift and flowing wells were producing through open tubing. At the present time these wells are producing against high back pressures which, in a number of cases, exceed the operating pressures of two or three years ago.'

Table Showing the Status of Wells in the Dominguez Field Before and After the Commencement of Gas Storage.

Well.	Before Injection. Status.	After Four Months Gas Injection. Status, 1st September, 1928.	Tubing pressure lb. per sq. in.	Casing pressure lb. per sq. in.
Callender—				
1	Gas-lift-open-flow	Flowing-beaned	145	170
2	Flowing-open-flow	Flowing-beaned	145	170
8	Gas-lift-open-flow	Gas-lift-beaned	10	280
9	Gas-lift-open-flow	Flowing beaned	10	140
10	Gas-lift-open-flow	Gas-lift	15	160
15	Gas-lift-beaned	Flowing-beaned	110	240
18	Gas-lift	Gas-lift	15	260

Table Showing the Status of Wells in the Dominguez Field Before and After the Commencement of Gas Storage—contd.

Well.	BEFORE INJECTION. Status.	AFTER FOUR MONTHS GAS INJECTION. Status, 1st September, 1928.	Tubing pressure lb. per sq. in.	Casing pressure lb. per sq. in.
Hellman—				
1	Gas-lift-open-flow .	Flowing-beaned .	90	180
2	Gas-lift-open-flow .	Flowing-beaned .	30	150
4	Gas-lift-open-flow .	Flowing-beaned .	160	260
5	Gas-lift-open-flow .	Flowing-beaned .	155	230
6	Gas-lift-open-flow	Flowing-beaned .	130	260
9	Gas-lift-open-flow	Flowing-beaned .	0	130
11	Gas-lift-open-flow .	Gas-lift . .	10	120
13	Gas-lift-open-flow .	Flowing-beaned .	26	170
Reyes—				
2	Flowing-open-flow .	Flowing . .	10	150
3-B.	Pumping . .	Shut-in . .	..	260
4	Pumping . .	Shut-in . .	..	260
5	Flowing-open-flow .	Flowing-beaned .	100	270
8	Gas-lift-open-flow .	Flowing-beaned .	150	320
9	Gas-lift-open-flow .	Pumping .	0	80
12	Gas-lift-open-flow .	Gas-lift . .	10	170
13	Pumping . .	Pumping no back pressure.	..	..
14	Gas-lift-open-flow	.	..	..

Plate 17 'is a graph of oil and gas production and the formation gas-oil ratio for the Callender, Hellman, and Reyes leases during the years 1926, 1927, and to September 1st, 1928. It is interesting to note that although 10 wells were taken off production and used as injection wells, 22 other wells are beaned back, and 4 pumping wells are operating against high back pressure, daily oil production from the field is closely following the normal oil decline curve established before gas storage was started. Incidentally this proves the effectiveness of repressuring in stimulating the production of oil'.

Results of repressuring in the Salt Creek field, Wyoming.

Plate 18 illustrates the results obtained by the biggest repressuring project in the United States at the time of my visit (August, 1928). This project is being carried out in the Salt Creek field where dry gas, supplemented by the unstable lighter fractions, propane and butane, from the gasoline stabilising plants is used to build up pressure in the formation. In this field the total volume of gas (in round figures) returned to the sand up to July 1st, was 11,216,272,000 cubic feet. At the time of my visit approximately thirty million cubic feet of gas, of which 2¾

million consisted of propane and butane, were being injected daily through 49 wells at a pressure of 150 lbs. per square inch. The estimated increase in daily production due to repressuring after twelve months operation amounted to 73 per cent. of the anticipated production without repressuring.

The above examples, typical of a much greater number of repressuring projects studied, are sufficient to illustrate the great increases in recovery obtainable by this method and also its superiority to vacuum as a secondary method of recovery.

The majority of American technologists agree that, where it has not been prematurely applied, vacuum has resulted in increased recovery in many fields, but they are also unanimously agreed that the majority of fields, which respond to vacuum, would yield much greater increases in recovery if subjected to repressuring. During the last decade, vacuum has been extensively employed in the Mid-Continent area but, during the last two or three years, the use of vacuum has been largely discontinued and its place taken by pressure. It is no exaggeration to state that in this area the remaining vacuum plants are operated solely for competitive purposes or for gasoline extraction. Even for the latter purpose the vacuum system is rapidly losing ground as producers believe that the loss of the lighter constituents from the crude oil and its resultant loss of mobility outweigh the revenue derived from gasoline extraction.

The examples cited above include repressuring with air, dry gas, and wet gas, all of which have resulted in large increases of recovery. As these various media were employed under widely different field conditions, it is impossible to draw from these examples reliable conclusions as to their relative merits, but it is believed by American technologists that wet gas is the most efficient medium and air the least. Strong theoretical grounds supporting this belief are to be found in the relative solubilities in crude oil of these three media, that of wet gas being the greatest and that of air the least. The practical difficulties in the use of air also, are sometimes considerable. The chief objections to its use are, the corrosion of equipment, particularly in wells that are producing water with the oil; the greater tendency to the formation of emulsions in such wells; the contamination of fuel gas; and the explosion hazard in the compression of air-gas mixtures.

The conditions in the oilfields of Burma, apart from the reserves of Twingon and Beme, appear to be such that large increases in recovery may be expected from these fields by repressuring. The Burmah Oil Company have already experimented with the method in the Yenangyaung field with encouraging results and a considerable increase in activities along these lines in the areas operated by that company is anticipated.

Possibilities of successful repressuring in the oilfields of Burma.

As regards the reserves of Twingon and Beme, it is doubtful whether the difficulties, consequent on the competitive conditions existing there, are not such as to render repressuring impracticable. Another factor which would operate against successful repressuring here, is the prevailing practice of group production. With as much as 1,000 feet of perforated pipe in some of the wells in the reserves it is inevitable that much of the gas returned to the formation would be dissipated in unproductive sands. There would, in fact, be a tendency for the greater part of the gas to enter such sands in preference to productive ones, as the pressure in the former would normally be less than in the latter and the gas would naturally take the path of least resistance. Yet another difficulty is the congestion of wells in these areas, a condition which would render the prevention of the escape of gas to the wells without it bringing with it its quota of oil (always a difficult problem in repressuring work) more than usually difficult. These difficulties, however, may not prove insuperable and any attempt to secure the co-operation of the competing companies for experimental purposes should be encouraged. If this co-operation is not obtainable, or if the results of such experiments should prove discouraging, it will be necessary to adopt some other secondary method of recovery in these areas.

If repressuring is definitely impracticable, I am aware of no other method, short of underground mining, that is as likely to succeed in increasing recovery in these areas as the application of vacuum. The evils of the premature application of vacuum are fully realised, but there can be no doubt that its proper application has prolonged the economic life of many fields and resulted in increased recovery. The conditions obtaining in the reserves in relation to the repressuring and vacuum questions were discussed with many of the leading technole-

Vacuum as an alternative to repressuring in the reserves of Twingon and Beme.

gists in the States. Without exception they were in agreement that the conditions are far from ideal for repressuring, while several expressed the opinion that the conditions of high porosity of the formation and close spacing of the wells, which characterise these areas, are conducive to large increases in recovery under vacuum.

ILLUSTRATIONS—

ON SOME UNDESCRIBED FRESHWATER MOLLUSCS FROM VARIOUS PARTS OF INDIA AND BURMA.* BY B. PRASHAD, D.SC., F.R.S.E., F.A.S.B., *Superintendent, Zoological Survey of India.* (With Plate 19.)

This short paper deals with a number of freshwater Gastropod and Pelecypod fossils which have been from time to time, submitted to me for report by the authorities of the Geological Survey of India and Mr. F. E. Eames of the Burmah Oil Company. The different species are of no special interest from the geological point of view, but to some extent help in understanding the distribution and relationships of the recent to the fossil forms.

I have to express here my thanks to the authorities of the Geological Survey of India for giving me the opportunity of examining these interesting fossils, and am also indebted to Mr. F. E. Eames for the privilege of describing the two fossil Unionids from Burma. The types of the new species are all preserved in the collections of the Geological Survey of India, Indian Museum, Calcutta.

Family: VIVIPARIDAE.

This family is represented by a new species of the genus *Viviparus* Montford, which was collected by Mr. S. M. Hasan, Engineer-in-charge of the new Nerbudda Bridge, from the debris raised while sinking foundation-wells for the bridge. The bridge is on the Jubbulpore-Itarsi branch of the Great Indian Peninsula Railway, and is situated about 23½ miles south-west of Jubbulpore, with an approximate latitude of 23°N. and a longitude of 79° 24′E. The shells, according to the collector, 'were found in the set of wells inside the north bank, at about 18 feet below the river bed or about 50 feet below the natural ground at the place. The marked difference in the geological formation at this place and the opposite bank was the absence of the conglomerate beds which thinned out from south to north and the presence of good clay'. The specimens were handed over to Mr. H. Crookshank of the Geological Survey of India, who forwarded them to me for report. Two of the specimens are only

* Published by permission of the Director, Zoological Survey of India.

casts of shells, while the third is a fairly well preserved young shell embedded in a clayey matrix. They represent an undescribed species of the genus *Viviparus*, which is allied to the recent *V. dissimilis* (Müller)[1], and to some extent to the Intertrappean *V. normalis* (Hislop).[2] The species is described below under the name *V. hasani*.

VIVIPARUS HASANI, sp. nov.

The species is of medium size, the largest cast in the series collected not exceeding 24 mm. in length. The shell is conical-ovoid, solid and with the surface almost smooth. It consists of three to four whorls, but the apex, which is eroded, must have consisted in addition of one to one and a half whorls. The spire is elongate, conical, more than half the length of the shell. The suture, which is markedly oblique, is moderately impressed. The whorls are a little oblique, not greatly swollen, and increase gradually in size. The body-whorl, as seen in dorsal view, is somewhat rhomboidal in outline, though it becomes much wider from about the middle towards the aperture. The aperture is not complete in any of the specimens, but appears to be somewhat ovoid. The shell is umbilicate, but the columella is not well developed. The complete young shell is dirty white in colour.

Measurements (in millimetres).

		Holotype.	
Total length	11·8	23	14
Maximum diameter	10	17·8	12
Height of aperture	..	11	8
Maximum diameter of aperture . . .	..	8·9	7·6

Remarks :—The relationships and provenance of the species have been discussed above, and it is only necessary to add that it is geologically not very old. Its age is probably the same as that of the type from the Nerbudda alluvial deposits described as *Vivipara bengalensis* (Lamarck) by Annandale.[3]

[1] For an account of this species see Preston, *Faun. Brit. Ind., Freshw. Moll.*, p. 87, (London, 1915).
[2] Hislop, *Quart. Journ. Geol. Soc. London*, XVI, p. 166, pl. v, figs. 2a, 2b, (1860). See also Prashad, *Mem. Ind. Mus.*, VIII, p. 192, (1928).
[3] Annandale, *Rec. Geol. Surv. Ind.*, LI, p. 366, (1921).

Family : UNIONIDAE.

LAMELLIDENS Simpson.

1900. *Lamellidens*, Simpson, *Proc. U. S. Nat. Mus.*, XXII, p. 854.
1915. *Lamellidens*, Simpson, *Descr. Cat. Naiades*, p. 1165.
1927. *Lamellidens*, Prashad, *Rec. Geol. Surv. Ind.*, LX, p. 308.

The genus *Lamellidens* Simpson comprises a number of closely allied species of Unionidae which are widely distributed in India and Burma. The recent species of the genus are catalogued in Simpson's invaluable work cited above, while references to the fossil species from different parts of India are included in my paper referred to above.

In the collection under report the genus is represented by four forms, two from Burma and two from the Siwaliks in the Punjab. Unfortunately the fossils from the Siwaliks are represented by casts only, while one of the very interesting types from Burma consists of only a single incomplete shell. In no case it is possible to study the hinge of the species, but I have no doubt whatsoever about the generic position of the different forms. In the case of the Burmese forms, further, the age of the strata from which the fossils were collected, was not determined. In view of what has been stated above I have not, except in one case, thought it desirable to give any specific names to the various forms, but publish photographs of the different types for future reference.

LAMELLIDENS PROCTORI, sp. nov.

(Plate 19, figs. 4-7.)

This new species of the genus *Lamellidens*, which I associate with the name of the collector, Mr. E. Proctor, is the first undoubted species of the genus *Lamellidens* to be found as a fossil in Burma; the generic position of the species *Lamellidens* (?) *quadratus* Annandale is, as the author[1] remarked, 'doubtful and could not be ascertained without examination of the hinges'.

The species may be described as follows:—

Shell of medium size, elongate-elliptical, rather thin, compressed, very inequilateral, posteriorly elongated and with a narrow, greatly

[1] E. Annandale, *Rec. Geol. Surv. Ind.*, LV, p. 103, (1923).

compressed posterior wing marked off by a low but prominent ridge. Surface almost smooth; showing only traces of lines of growth. Umbonal region in anterior half of shell; beaks not at all swollen or prominent, without any sculpture. Dorsal outline nearly straight, running gradually into the evenly rounded anterior end; ventral outline somewhat arched, except in its posterior third where it curves abruptly to form the ventral margin of the posterior beak. Periostracal colour in the three specimens varies from ashy grey to metallic greyish brown. Hinge unknown.

Locality :—Three shells of this species were collected by Mr. E. Proctor on 23rd March 1928, at Peg. No. 45 in a small tributary of Thapan Choung, a branch of Yu River in the Yenan area, Upper Chindwin.

Measurements (in millimetres).

	Holotype	Paratype	C
Length	24·8	47·2	56·4
Maximum breadth	13·5	..	..
Height	20·2	22·4	27·5

I have selected the smallest specimen as the holotype as it is the most complete of the three specimens available; the other two specimens are greatly compressed and do not show the true form of the species.

Remarks :—*L. proctori* is closely allied to the recent species *L. corrianus* (Lea),[1] but is distinguished by its shape and the form and situation of the umbones. I have no doubt that all the three specimens, which I refer to this species, are conspecific, and the differences in their form are due to distortion during the process of fossilisation.

LAMELLIDENS sp.

(Plate 19, figs. 8, 9.)

The fossil, which I record here as *Lamellidens* sp. and photographs of which are reproduced as figures 8, 9 on Plate 19, is represented by a single incomplete shell from the same locality as the form described above under the name *L. proctori*.

[1] See Simpson, *Descr. Cat. Naiades*, p. 1175, (1915).

In the only available fossil the two valves are closely compressed together, and it is not possible to study the hinge of the species. The umbonal area and the posterior wing more particularly in the left valve are, however, well preserved, and even though it is not possible to be certain about the exact shape of the species, I have little doubt that the form under consideration belongs to the genus *Lamellidens*, and is of the group of species *L. generosus* (Gould)[1] which is dominant in Burma. The characters, which confirm this conclusion, are the very forwardly placed, greatly compressed and not at all prominent umbones and the well developed posterior wing.

LAMELLIDENS sp.

(Plate 19, figs, 10, 11.)

A large number of casts (14,789—14,790) of a species of the genus *Lamellidens* were collected by Dr. G. E. Pilgrim from strata of the Middle Siwalik age at Asnot, Salt Range and at Mithrala, Attock District (Dhok Pathan zone) in the Punjab. Unfortunately none of the specimens is complete and it is not possible, therefore, to be definite about the specific identification of the mussel in question. It comes close to the species *L. jammuensis* Prashad, which was described by me[2] from the Siwaliks near Nagrota, Jammu, and which I assigned to the Upper Siwalik period.

For future reference I publish photographs of two of the casts.

LAMELLIDENS sp.

(Plate 19, figs. 12, 13.)

Two lots of casts, Nos. 14,791 from Chinji, Salt Range, and 14,792 from near Chinji, Salt Range, from Lower Siwalik strata, collected by Dr. G. E. Pilgrim, are also not possible to identify specifically. They differ from the species from the Middle Siwalik strata referred to above, and are probably distinct from it. The distinguishing features of this form, so far as can be judged from the casts available, are the much smaller size, the prominent and much more tumid umbones and the less elongated beak area.

[1] See Prashad, *Rec. Ind. Mus.*, XXIV, p. 107, pl. ii, figs. 12-17, (1922).
[2] Prashad, *Rec. Geol. Surv. Ind.*, LX, p. 309, pl. xxv, fig. 1, (1927).

EXPLANATION OF PLATE.

All the figures are reproduced natural size, from direct photographs of the specimens.

VIVIPARUS HASANI, sp nov.

FIG. 1.—Holotype embedded in a clayey matrix (14,783.)
FIGS.—2, 3.—Casts of two shells. (14,784—14,785.)

LAMELLIDENS PROCTORI, sp. nov.

FIGS. 4, 5.—Right and left valves of the Holotype. (14,786.)
FIGS. 6, 7.—Right and left valves of another specimen. (14,787.)

LAMELLIDENS sp.

FIGS. 8, 9.—Right and left valves of a species of *L. generosus* group (14,788.)

LAMELLIDENS sp.

FIGS. 10, 11.—Right and left valves of casts of a species near *L. jammuensis* from the Middle Siwaliks collected at Mithrala, Attock District. (14,789—14,790.)

LAMELLIDENS sp.

FIGS. 12, 13.—Left valves of casts of two specimens from Lower Siwaliks collected near Chinji, Salt Range. (14,791—14,792.)

SECOND NOTE ON THE NORTH-WEST HIMALAYAN EARTHQUAKE OF THE 1ST FEBRUARY, 1929. BY A. L. COULSON, M.SC., D.I.C., F.G.S., *Assistant Superintendent, Geological Survey of India.*

I. INTODUCTION.

Additional information.

Since the publication of the author's previous paper concerning the epicentre of the North-West Himalayan Earthquake of the 1st February, 1929,[1] additional instrumental records of the earthquake have been received from the observatories at Colombo and Dehra Dun. The first note was written with the idea of drawing attention to this shock and with a view to obtaining additional information. This was successful inasmuch as it resulted in the receipt of the valuable records from Dehra Dun. With the aid of the additional information, a more complete study of the records has been undertaken; this is embodied in the following paper, which also contains, for ready reference, many of the details given in the previous paper.

II. POSITION OF THE EPICENTRE.

Position near the frontier between Buner and Hazara.

The observers' reports of the earthquake indicated that the epicentral tract lay in the area between Drosh, Rawalpindi, Peshawar, Srinagar and Gurais.[2] For the purpose of analysing the previous instrumental records. the epicentre was taken as being some 25 miles north-west of Abbottabad on the junction between Buner and Hazara. This position is still adopted in the present paper and lies approximately 405 miles (650 km.) from Dehra Dun; 1,115 miles (1,795 km.) from Colaba (Bombay); 1,270 miles (2,040 km.) from Alipore (Calcutta); 1,740 miles (2,800 km.) from Kodaikanal; and 1,955 miles (3,150 km.) from Colombo.

Epicentral tract unstable region.

The epicentral tract is a very unstable region.[3] It is probably the most interesting seismic region with which we in India have to deal. It is certainly the most critical area in our studies of mountain building in general and of the Himalayas in particular.[4] The

[1] A. L. Coulson, *Rec. Geol. Surv. Ind.*, LXII, pp. 279-289, (1930).
[2] *Ibid.*, p. 281.
[3] F. de Montessus de Ballore, *Mem. Geol. Surv. Ind.*, XXXV, p. 6, (1904).
[4] Notes by Dr. C. S. Fox.

orographic axes of the Himalayas sweep round with a marked change of direction and are accompanied by faulting, the structural relations being very complicated. The Himalayan folds here 'appear to have resulted from a thrust southward against the bows of a horst of the Archaean peninsula. Frequent small slips along thrust planes inclined (dipping) gently N.N.W. are to be expected in this region.'[1] This is borne out by the recording of 20 distinct shocks in the 12 months immediately preceding the shock of the 1st February.[2] Unfortunately, however, it was not possible for an officer of the Geological Survey of India to examine the epicentral tract. Had an inspection been possible, much additional information would doubtlessly have been obtained.

Geological notes.

Very little information concerning the geological nature of the country along the borders of Buner and Hazara is available. Middlemiss[3] has described the geology of Hazara and the Black Mountain and shows the region in the vicinity of the border as being composed of gneissose and schistose crystalline and metamorphic rocks. He places their age as Palaeozoic or older,[4] but on the latest geological map of India (at present in course of publication), the rocks are termed 'unclassified crystallines, gneisses, etc.' On this same map and on Middlemiss' map, the Buner country is left uncoloured.

III. INSTRUMENTAL RECORDS.

Colombo.

The records received from Colombo gave in Indian Standard Time[5] the times of the different phases of the shock as under :—

	Day.	Hour.	Minute.	Second.
P . .	1	22	50	21
S . .	1	22	54	23
L . .	1	22	56	41
M . .	1	23	3	33
F . .	2	1	36	..

Amplitude, 19·5 mm.

P=Time of commencement of First Preliminary Tremors.
S=Time of commencement of Second Preliminary Tremors.
L=Time of commencement of Long Waves.
M=Time of Maximum Movement.
F=End of Shock.

[1] Notes by Dr. C. S. Fox.
[2] Coulson, *op. cit.*, pp. 288, 289.
[3] *Mem. Geol. Surv. Ind.*, XXVI, pp. 1-302, (1896).
[4] *Ibid.*, p. 9 (table).
[5] Indian Standard Time is 5 hours 30 minutes ahead of Greenwich Mean Time. Unless otherwise stated, all times given in this paper correspond with Indian Standard Time.

The actual time for S given by the Colombo observatory was 22 hours 51 minutes 21 seconds. However, if one considers the time intervals between P, S and L utilising the above time for S, one obtains S – P=1 minute and L – P=6 minutes 20 seconds. The corresponding interval, S – P, for an interval, L – P=6·3 minutes, should be about 3·9 minutes according to the generally accepted epicentral tables. One can but conclude that the time, S, given by the Colombo observatory is incorrect. The time adopted, S=22 hours 54 minutes 23 seconds, was calculated by the author from a copy of the seismographic record at Colombo. This gives the more reasonable interval, S – P=4·04 minutes.

The following information was received from the Geodetic Branch Office of the Survey of India at Dehra Dun, where the seismograph is of Omori type, one pendulum lying east and west. The times are according to Indian Standard Time and accurate time is stated to be available.

Dehra Dun.

	Day.	Hour.	Minute.	Second.	Remarks.
P . .	1	22	46	20	Record distinct.
S . .	1	22	47	00	" "
L . .	1	22	47	40	" "
M . .	1	22	48	..	
F . .	2	5	..	..	

Estimated distance, 260 miles.

The earthquake was termed 'Sargodha, Punjab.'

F was given as 'about 0·5 hrs. on 23rd.', the date '23rd' being an obvious typists's error.

For ready reference, the details from Colaba, Alipore and Kodaikanal[1] are given in the following table :—

Previous records.

	COLABA.				ALIPORE.				KODAIKANAL.			
	Day.	Hour.	Minute.	Second.	Day.	Hour.	Minute.	Second.	Day.	Hour.	Minute.	Second.
S .	1	22	48	15	1	22	48	44	..	..	..	..
P .	1	22	50	31	1	22	51	7	1	22	52	24
L .	1	22	51	36	1	22	52	20	1	22	55	18
M .	1	22	56	50	1	22	52	46	1	23	2	6
F .	2	0	37	..	1	23	53	31	2	0	7	54

[1] Coulson, *op. cit.*, pp. 282-285.

IV. ANALYSIS OF THE RECORDS.

Previous impossible results.

It was shown[1] that the usual methods of locating the epicentre gave impossible results from the records at Colaba, Alipore and Kodaikanal. The additional records from Dehra Dun and Colombo give equally impossible results as will be seen from the following brief study of the time intervals between the various phases, P, S and L.

Colombo and Dehra Dun.

If one utilises the interval, L – P=6 minutes 20 seconds, for Colombo, epicentral tables indicate that the epicentral distance of this earthquake from Colombo is 21⅜°, or roughly 1,515 miles; whereas the distance from the supposed epicentre to Colombo is 1,955 miles. Similarly, assuming the correctness of the time phases given by the Survey of India, the epicentral distance of the earthquake from Dehra Dun can be calculated from the interval, S – P, as 260 miles and from the interval, L – P, as 375 miles. The distance of Dehra Dun from the supposed epicentre is approximately 405 miles.

Epicentre indicated by observers' reports assumed to be correct.

Thus there are large differences in the position of the epicentre when this is calculated by epicentral tables and when inferred from observers' reports. One must assume the latter to be correct. For instance, when calculated from the records of Colaba, Alipore and Kodaikanal, assuming the long or surface waves (Rayleigh waves) had a velocity of 3·8 kilometres per second, the epicentre was indicated as being near Dholpur;[1] but no reports of the occurrence of any sensible shock were received from Dholpur.

Epicentral tables based upon observations of numerous earthquakes.

The epicentral tables used in the calculations are based, as regards L – P, on the assumption of a velocity of 3·8 km. per second for the long waves, the usual velocity of the long waves.[2] The intervals, L – P, and S – P, and the epicentral distance in the tables have been calculated from time observations of numerous earthquakes. Accordingly, if any reliance at all is to be

[1] Coulson, *op. cit.*, p. 287.

[2] O. Klotz., *Bull. Seis. Soc. Amer.*, VII, pp. 67-71, (1907) as cited in C. Davison, 'A Manual of Seismology,' Cambridge, p. 147, (1921).

placed on the time observations of the five recording stations, one can but conclude that the usual rates of propagation of the preliminary and secondary tremors and the long waves are not applicable to this earthquake of the 1st February, 1929.

Differences not explained by depth of focus.

It is not thought possible that the differences in rate are entirely due to the effect of depth of focus of the earthquake, though depth must influence the rates to a certain extent.[1] As Davison notes,[2] 'The forms of the time-curves for individual earthquakes vary within certain narrow limits, the variation depending partly on the depth of the focus, partly perhaps on the paths traversed by the waves.'

Consideration of the paths of the waves.

In the author's previous paper,[3] an investigation was made of the paths of the long or surface waves from the position of the supposed epicentre to the recording stations of Colaba, Alipore and Kodaikanal. It was assumed that the long waves had a velocity of 3·8 kilometres per second in 'rock' and their velocity in 'alluvium' was calculated by considering the paths to the three recording stations as consisting of a definite amount of rock with the remainder alluvium. The previous results are given in the following tables, together with those obtained from a consideration of the path to Dehra Dun, compared with that to Colaba and, also, that to Alipore :—

Recording station.	Epicentral distance in kilometres.	Alluvium in kilometres.	Rock in kilometres.	L	
				Minute.	Second.
Dehra Dun . . .	650	50	600	47	40
Colaba	1,795	815	980	51	36
Alipore	2,040	625	1,415	52	20
Kodaikanal . . .	2,800	710	2,090	55	18

[1] H. Jeffreys, 'The Earth,' Cambridge, pp. 135-136, (1929).
[2] C. Davison, 'A Manual of Seismology,' Cambridge, p. 145, (1929).
[3] *Op. cit.*, pp. 286-287.

	A.	B.	C.	D.	E.
Alluvium in kilometres	+765	+575	—190	—105	+85
Rock in kilometres	+380	+815	+435	+1,110	+675
Time interval in seconds	236	280	44	222	178
Velocity in alluvium in kilometres per second.	5·6	8·8	2·7	1·5	231[1]

The figures in each of the columns, A to E, are derived from a study of each of the following pairs of stations, respectively :—

A. Colaba and Dehra Dun.
B. Alipore and Dehra Dun.
C. Alipore and Colaba.
D. Kodaikanal and Colaba.
E. Kodaikanal and Alipore.

The plus sign denotes that the length of the portion of the path to the first-named station lying in alluvium or rock exceeds the length of the portion of the path to the last-named station through the same medium by the amount stated. Thus for C, the path to Alipore traverses 190 kilometres less alluvium and 435 kilometres more rock than that to Colaba.

Use of amounts of alluvium and rock in path insufficient to explain time differences.

Only five intervals between the times of arrival of the long waves, L, at different stations have been considered, but these are sufficient to show large differences for the velocity in alluvium as distinct from rock. Accordingly it must be concluded that the assumption that the long waves in alluvium have a different velocity from the usual velocity of 3·8 km. per second, when taken in conjunction with the adoption of the usual velocity in rock, is insufficient to explain the times given by the recording stations.

Determination of velocity of long waves.

One may now consider what is the velocity, V, of the long waves of this earthquake, assuming that the velocity is the same throughout all parts of the paths to the recording stations. The following table, which also contains, for ready reference, the results previously obtained for Colaba, Alipore and Kodaikanal,[2] gives the results obtained by considering the differ-

[1] Coulson, *op. cit.*, footnote No. 1, p. 287.
[2] *Ibid.*, pp. 285-286.

ences in time of arrival of the long waves at each of the following pairs of recording stations:—

	A.	B.	C.	D.	E.	F.	G.	H.	I.	J.
Interval in seconds . .	236	280	458	541	44	222	305	178	261	83
Distance in kilometres .	1,145	1,390	2,150	2,500	245	1,005	1,535	760	1,110	350
Velocity of the long waves in km. per second.	4·8	5·0	4·7	4·6	5·6	4·5	4·4	4·3	4·2	4·2

A. Dehra Dun and Colaba.
B. Dehra Dun and Alipore.
C. Dehra Dun and Kodaikanal.
D. Dehra Dun and Colombo.
E. Colaba and Alipore.
F. Colaba and Kodaikanal.
G. Colaba and Colombo.
H. Alipore and Kodaikanal.
I. Alipore and Colombo.
J. Kodaikanal and Colombo.

Higher velocity than usual.

The average of these ten figures for the velocity of the long waves is 4·6 kilometres per second. All the results are higher than the usual figure of 3·8 kilometres per second. Accordingly, though the figure of 4·6 is only an approximation, one can safely say that the long waves in this earthquake had a higher velocity than usual.

Time of origin of earthquake.

Assuming that the long waves had a velocity of 4·6 kilometres per second in all parts of their courses to the recording stations, it is a simple matter to calculate a value for the time of origin of the shock at the epicentre, O. The following table gives the results so obtained:—

Recording station.	Distance from epicentre in kilometres.	L		Calculated interval L – O		O	
		Minute.	Second.	Minute.	Second.	Minute.	Second.
Dehra Dun .	650	47	40	2	21	45	19
Colaba . .	1,795	51	36	6	30	45	6
Alipore . .	2,040	52	20	7	23	44	57
Kodaikanal .	2,800	55	18	10	9	45	9
Colombo . .	3,150	56	41	11	25	45	16

The mean of these times is 22 hours 45 minutes 9 seconds Indian Standard Time or 17 hours 15 minutes 9 seconds Greenwich Mean Time, on the 1st February, 1929. Most of the observing stations without instruments gave either 22 hours 45 minutes or slightly later times; and so the calculated time of origin is as well within agreement with the observed times as can be expected from inaccurate observation.

First preliminary tremors.

One may now pass to a consideration of the times, P and S. The time L can usually be obtained from the records with greater accuracy than either P or S. So the time of origin has been obtained from the times of arrival of the long waves and not from either the first or second preliminary tremors. Assuming that the time of origin was 22 hours 45 minutes 9 seconds, one obtains the following figures for V_1, the mean velocities of the first preliminary tremors :—

Observing station.	P		Interval P-O		Epicentral distance in		V_1 km. per sec.
	Minute.	Second.	Minute.	Second.	Miles.	Degrees.	
Dehra Dun . .	46	20	1	11	405	5·8°	9·2
Colaba . .	48	15	3	6	1,115	15·9°	9·7
Alipore . .	48	44	3	35	1,270	18·1°	9·5
Kodaikanal . .	.	..	..	..	1,740	24·9°	..
Colombo . .	50	21	5	12	1,955	27·9°	10·1

The mean velocities of the first preliminary tremors are higher than usual and except for the discordance between Alipore and Colaba, increase with arcual distances, as is to be expected. The velocity of 10·1 kilometres per second for an arcual distance of 28° may be compared with the usual velocity of 10·9 kilometres per second for an arcual distance of 60°.[1]

[1] Davison, *op. cit.*, p. 147.

Second preliminary tremors.

Similarly the mean velocities, V_2 of the second preliminary tremors may be determined with the results given in the following table :—

Observing station.	S		Interval S – O		Epicentral distance in degrees.	V_2 km. per sec.
	Minute.	Second.	Minute.	Second.		
Dehra Dun . .	47	00	1	51	5·8°	5·9
Colaba . . .	50	31	5	22	15·9°	5·6
Alipore . . .	51	7	5	58	18·1°	5·7
Kodaikanal . .	52	24	7	15	24·9°	6·4
Colombo . .	54	23	9	14	27·9°	5·7

These velocities do not consistently increase with arcual distances though they are alike in being higher than usual. For instance, Davison [1] gives the velocity of 4·8 kilometres per second for an arcual distance of 30°. The discordance may be due to the fact that other compressional and distortional pulses are present and that these have confused the interpretation of the seismograms.[2]

V. SUMMARY AND CONCLUSIONS.

1. Instrumental records from Dehra Dun and Colombo regarding the earthquake of the 1st February, 1929, have been given.

2. These additional records and the previous records from Colaba, Alipore and Kodaikanal have been analysed and found to show a distinct abnormality compared with the usual results obtained in the study of earthquakes. The usually adopted velocity for the long or surface waves of 3·8 kilometres per second does not hold in this earthquake.

3. The assumption that the long waves have a different velocity in alluvium from that in rock, taken in conjunction with the adoption of the usual velocity for their propagation in rock, does not explain the time differences in the records.

[1] Davison, *op. cit.*, 147.
[2] Jeffreys, *op. cit.*, p. 95.

4. It is concluded that the long waves of this earthquake have the relatively high velocity of approximately 4·6 kilometres per second.

5. Adopting this velocity, the time of origin of the shock at the epicentre has been calculated as 22 hours 45 minutes 9 seconds Indian Standard Time, or 17 hours 15 minutes 9 seconds Greenwich Mean Time on the 1st February, 1929.

6. The first and second preliminary tremors also have a higher velocity than is usual, the velocity of the former increasing comparatively regularly with arcual distance.

MISCELLANEOUS NOTES.

Tremolite from near Jasidih, Bihar.

In May, 1927, Babu Pannalal Jogannath, of Katrasgarh, East India Railway, brought certain amphibolitic material to the Geological Survey of India for identification, its locality of origin being given as near the villages of Ghogh (24° 32′ 45″ : 86° 38′ 12″) and Dhawani (24° 30′ : 86° 39′ 15″), close to Jasidih, Santal Parganas, Bihar. Exact details of the field occurrence could not be furnished, but the sequence from highest to lowest was as follows :—

1. Tremolite with a small amount of a talcose mineral and a little iron oxide and ? rutile.
2. Tremolite with more talcose mineral and iron oxide and a little ? rutile.
3. Tremolite, with quartz.

The abundance, purity and coarseness of the tremolite appeared to increase with depth.

In October, 1927, similar material was also brought to this Department, this time by Mrs. R. Hay of the Jasidih Mineral Co., Jasidih, the locality, however, being given as 'near Jasidih'. This material is registered in the rock collection of the Geological Survey of India as Nos. 37/740 (18145), 37/741 (18146), 37/742 and 37/743, the numbers of the microscope slides being given in parenthesis.

In February, 1928, the following analysis (I) by Messrs. J. and R. Hutchison of a so-called 'silica sand' was forwarded by the Jasidih Mineral Co. to this Department for interpretation :—

	I.	II.
	Per cent.	Per cent.
SiO_2	58·50	57·69
TiO_2	..	0·14
Al_2O_3	2·82	1·80
Fe_2O_3	1·60	0·00
FeO		0·55
MnO	trace	trace
MgO	23·28	24·12
CaO	13·58	13·19
K_2O	..	0·22
Na_2O	..	0·48
H_2O	*nil*	1·56
F	..	0·37
TOTAL	99·78	100·22
Deduct oxygen equivalent of fluorine	..	0·15
		100·07

In the analysis received, iron was specified as 'iron oxide' and 'ignition' was given as *nil*. The analysis in column II is that of a tremolite from Lee, Mass., U. S. A.[1], and it can clearly be seen that the so-called 'silica sand' is a practically pure tremolite. Repeated requests for a sample of the material analysed met with no response. Hence, although the analysis is of interest, it has not the same value as would attach to it were one certain that it applied to the tremolite registered in the collections of this Department; for upon the latter the physical data given below have been determined.

The specific gravity of the tremolite from Jasidih is 3·05. It is pale green in colour; and very brittle, due to the high development of the cleavage (110). When sections were inclined on a Federov stage, minute small twinning lamellæ parallel to (001) were visible.[2] The plane of the optic axes lies in the plane of symmetry (010). The angle of extinction, $\mathfrak{c} \wedge c = 15°$, and $\mathfrak{c}$ is situated in the obtuse angle β between the crystallographic axes *a* and *c*.

The following are the refractive indices of the tremolite for sodium light, determined by means of a Pulfrich total reflectometer, the section being almost parallel to the acute bisectrix but at about 45° to the optic axial plane [3]:—

$$\alpha = 1{\cdot}6029,$$

$$\beta = 1{\cdot}6175,$$

$$= 1{\cdot}6300.$$

$$\gamma - \alpha = 0{\cdot}0271.$$

When calculated from the indices by means of Bartalani's formula [4].

$$\cos V = \frac{\tan \varphi}{\tan \psi}, \text{ where } \cos \varphi = \frac{\beta}{\gamma} \text{ and } \cos \psi = \frac{\alpha}{\gamma}.$$

the optic axial angle, 2V=85° 6′. Actual measurements of the optic axial angle in slides 18145 and 18146 gave 2V=80°. These were corrected for the difference in refractive index of the hemisphere (1·650) and the mineral (β=1·6175).

[1] Ford, *Am. Journ. Sci.*, XXXVII, p. 179 (1914). O. Mügge, 'Rosenbusch's Mikroskopische Physiographie der Petrographisch Wichtigen Mineralien', Stuttgart, I, No. 2, pp. 512, 513 (1927).
[2] J. P. Iddings, 'Rock Minerals', New York, p. 357 (1911).
[3] C. Pulfrich, 'Das Total reflectometer', Leipzig, Plate III, Fig. 6 (1890).
[4] F. Becke, 'Tschermak's Lehrbuch der Mineralogie', Vienna, p. 211 (1921).

The foregoing results are given below in tabular form together with the values of other tremolites [1]:—

No.	α	β	γ	$\gamma-\alpha$	$c : c$	2V
I . .	1·5996	1·6131	1·6244	0·0248	16°39′	81°33′
II . .	1·6000	1·6155	1·6272	0·0272	15°25′	79°38′
III . .	1·6029	1·6175	1·6300	0·0271	15°	85°6′
IV . .	1·6022	1·6192	1·6347	0·0325	16°38′	86°29′

I. Tremolite, Gouverneur, N. Y. d = 2·997.
II. Tremolite, Switzerland. d = 2·980.
III. Tremolite, Jasidih, India. d = 3·05.
IV. Tremolite, Lee, Mass., U. S. A.

A. L. COULSON

Note on Sapphirine in the Vizagapatam District.

Sapphirine was first discovered in India by Mr. C. S. Middlemiss in 1902, and was described by him in a paper entitled ' Note on a Sapphirine-bearing rock from the Vizagapatam district '.[2] In this paper he states that he found in one place near Paderu (18° 04′ : 32° 42′) a rock containing this rare mineral. A later paper by Dr. T. L. Walker and Mr. W. H. Collins[3] written as the result of an examination of some further specimens collected by Middlemiss in 1903, reports the mineral from numerous places between Paderu and Gangrez Madgui, and considerably extends the information given in the original report.

The objects of the present note are (1) to show that rocks containing sapphirine are fairly common over a wide area in the Vizagapatam Hill Tracts situated about 25 miles to the east of the region noted by Walker and Collins, and (2) to add the refractive indices, and the optic axial angle to the optical constants of this mineral already published in our *Records*.

In April, 1924, I made a hasty traverse through the Vizagapatam Hill Tracts, and collected numerous rock specimens in the valleys between Longaparti (18° 11′ : 82° 59′) and Masavalsa (18° 12′ : 82° 54′), and also between Jalda (18° 07′ : 82° 54′) and Pedakota (18° 05′ : 82° 57′). On examining these specimens I found pieces of sapphirine-bearing rock collected from a number of different places scattered throughout these valleys. This region lies about 25 miles east of that in which Middlemiss first found sapphirine. In all probability this mineral is a common one over most of this part of the Eastern Ghats.

[1] O. Mügge, *loc. cit.*, p. 513.
[2] *Rec. Geol. Surv. Ind.*, Vol. XXXI, p. 38 (1904).
[3] *Op. cit.*, XXXVI, p. 1-18 (1907).

My specimens differ from Middlemiss' in that the sapphirine is less well developed. The mineral generally forms a thin rim round grains of hercynite, and separates that mineral from the hypersthene of which the bulk of the rock is composed. In Middlemiss' rock the thin rim has expanded at the expense of the hercynite, till that mineral has either completely disappeared, or is reduced to a mere core. The rock and mineral association in all the localities where sapphirine was found are indistinguishable from those already described by Middlemiss, and later, and more fully, by Walker and Collins.

The optical constants determined by Middlemiss are as follows :—

Pleochroism : strong.

$\mathfrak{a}$ = Very pale dirty orange or pinkish grey.

$\mathfrak{b}$ = Deep cobalt blue.

$\mathfrak{c}$ = Deep prussian blue.

Cleavage : distinct.

Extinction angle from 0° to 25° in sections showing $\mathfrak{a}$ and $\mathfrak{c}$ colours.

Biaxial, negative.

In addition to these Walker and Collins give some information as to the orientation of the crystallographic axes with respect to the cleavage plane.

Using Middlemiss' material, which is purer than my own, but otherwise identical, I have obtained the following additional optical properties :—

The refractive indices are :—

$$\alpha = 1{\cdot}714,\ \beta = 1{\cdot}718,\ \gamma = 1{\cdot}720.$$
$$2V = 62°.$$

The refractive indices have been obtained in the usual way by comparing grains of the mineral with liquids of known refractive index. For this comparison use was made of sodium light, and the Becke line test. The refractive indices of the immersion media were checked with a Zeiss variable refracting angle refractometer. By these means it is believed that the limits of error have been kept below 0·002.

The optic axial angle was obtained with the help of a Federov Universal Stage by direct observation of both optic axes in a thin section of the mineral. A suitable correction has been made for the error in the reading of this angle due to the difference in refraction between the mineral and the hemispherical glass of the instrument.

The refractive indices and the optic axial angle given by Ussing for this mineral from Fiskernäs in Greenland are :—

$$\alpha = 1{\cdot}705,\ \beta = 1{\cdot}709,\ \gamma = 1{\cdot}711.$$
$$2V = 68°.$$

Ussing used red light for the determination of the refractive indices, and sodium light for the optic axial angle. It is impossible to make an accurate comparison between Ussing's results for the refractive indices and mine, as he does not mention the wave length of his red light.

Using a red light similar to that described by Ussing I found that the refractive indices of the liquids used in my determination were about 0·005 lower than the figure for the same liquids measured in sodium light. By deducting this figure from my results an approximate idea of the refractive index of Indian sapphirine in red light can be obtained. This, however, does not allow for the difference in dispersion between the mineral and the liquids, a factor which might be of considerable importance.

Comparing the two sets of refractive indices in red light, it appears that the Indian mineral has a slightly higher refraction than the Greenland one. Its optic axial angle is on the other hand a little lower. These two small variations are probably due to the fact that iron has largely taken the place of magnesia in the Indian sapphirine, while the opposite is the case in the Greenland mineral.

H. CROOKSHANK.

On a Titaniferous Augite from Chaudrawati, Sirohi State, Rajputana.

Introduction.

The titaniferous augite in question occurs in a contact metamorphic product at the junction of a small plug of olivine-gabbro with a calcic rock, one mile east-north-east of Chaudrawati (24° 26′ 30″ : 72° 47′), Sirohi State, Rajputana. Its associated minerals are calcite, wollastonite, pectolite, quartz, microcline, orthoclase, plagioclase and magnetite. Near Kui (24° 28′ : 72° 50′), where a smaller plug of olivine-gabbro intrudes a similar calcic rock, prehnite also is found.

Descriptive notes.

The presence of titanium in the pyroxene was proved by the reactions of Gaubert [1] using concentrated sulphuric acid containing morphine in solution. After 24 hours, a distinct red colour was visible.

In the hand specimen, the augite was black. In thin section, its pleochroism was as follows :—

$\mathfrak{a}$=mauve,

$\mathfrak{b}$=mauve,

$\mathfrak{c}$=greenish brown.

Absorption : $\mathfrak{a} > \mathfrak{b} > \mathfrak{c}$

Dispersion : $\rho > v$

At its edges, the mineral is altered to a green variety of pyroxene, less pleochroic than the main mass and also at times in different optical orientation ; at others, the orientation is the same.

[1] P. Gaubert, *Bull. Soc. Franc. Min.*, XXXIII, pp. 324-26 (1910).
See also L. Lévy, *Comptes Rendus Acad. Sci. Paris*, CIII, pp. 1074-75 (1886).

The highest and lowest refractive indices, determined for sodium light by the Becke method using a solution of sulphur in methylene iodide, were as follows :—

$$\gamma_y = 1{\cdot}758 \pm {\cdot}001,$$

$$\alpha_y = 1{\cdot}734 \pm {\cdot}001,$$

$$\gamma_y - \alpha_y = 0{\cdot}024.$$

The refractive index β varies on account of the change in the optical character of this titaniferous augite. This change is discussed in the following section. When the augite is pseudo-uniaxial, $\beta = \omega = \alpha$, the mineral being positive. Assuming, however, an average optic axial angle of 2 V= 35°, β can be calculated as 1·736 by Bartalini's formula.[1] Efforts to measure the refractive indices of a polished fragment of the augite by means of the total reflectometer were unavailing.

Change in optical character.

The interest of the augite lies in the fact that its optical character varies. The mineral is always positive, but certain sections appear pseudo-uniaxial even when viewed with yellow and green monochromatic light. Generally, however, the augite is biaxial, but the optic axial angle changes greatly. Three determinations for green light measured by the Federov method gave results 2 V=36°, 34° and 72°, respectively. The measurements in these determinations were corrected for the difference in refractive index between the hemispheres and the mineral according to Plate No. 7 of Wright's memoir.[2]

The augite was twinned with fine lamellæ parallel to (001)[3] and exhibited one good and one weak cleavage in two of the three sections. In one section, β was almost in the twinning plane whilst the good (prismatic) cleavage was inclined to the axial plane at some 45°. In a second section, somewhat similar results were obtained, the good cleavage being inclined at about 30° to the optic axial plane. In a third section, two good cleavages of equal strength were visible ; these were the usual prismatic cleavages (110) and (1̄10). The optic axial plane made a small angle with the symmetry plane suggesting that the augite may be triclinic.

The results are very interesting but are not conclusive, as the dispersion of the mineral made it exceedingly difficult to obtain exact results and, also, the crystallographic directions were not plain. In addition, the correction applied for the index of refraction of the hemispheres can at best be only approximate for minerals with such high birefringence as possessed by this augite. One can definitely say, however, that the optical nature of this titaniferous augite changes from biaxial to pseudo-uniaxial and that its optic axial angle varies largely.

[1] F. Becke, 'Tschermak's Lehrbuch der Mineralogie,' Vienna, p. 211 (1921).

[2] F. E. Wright, 'The Methods of Petrographic-Microscopic Research. Their relative accuracy and range of application,' Washington (1911).

[3] J. P. Iddings, 'Rock Minerals,' New York, pp. 316-7 (1911).

The following are the registered numbers of the rock specimens in the collections of the Geological Survey of India, the numbers in parenthesis denoting the corresponding thin section :—36/787 (17595) ; 36/790 (17597) ; 36/791 (17598) ; and 36/795 (17601).

A. L. COULSON.

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V

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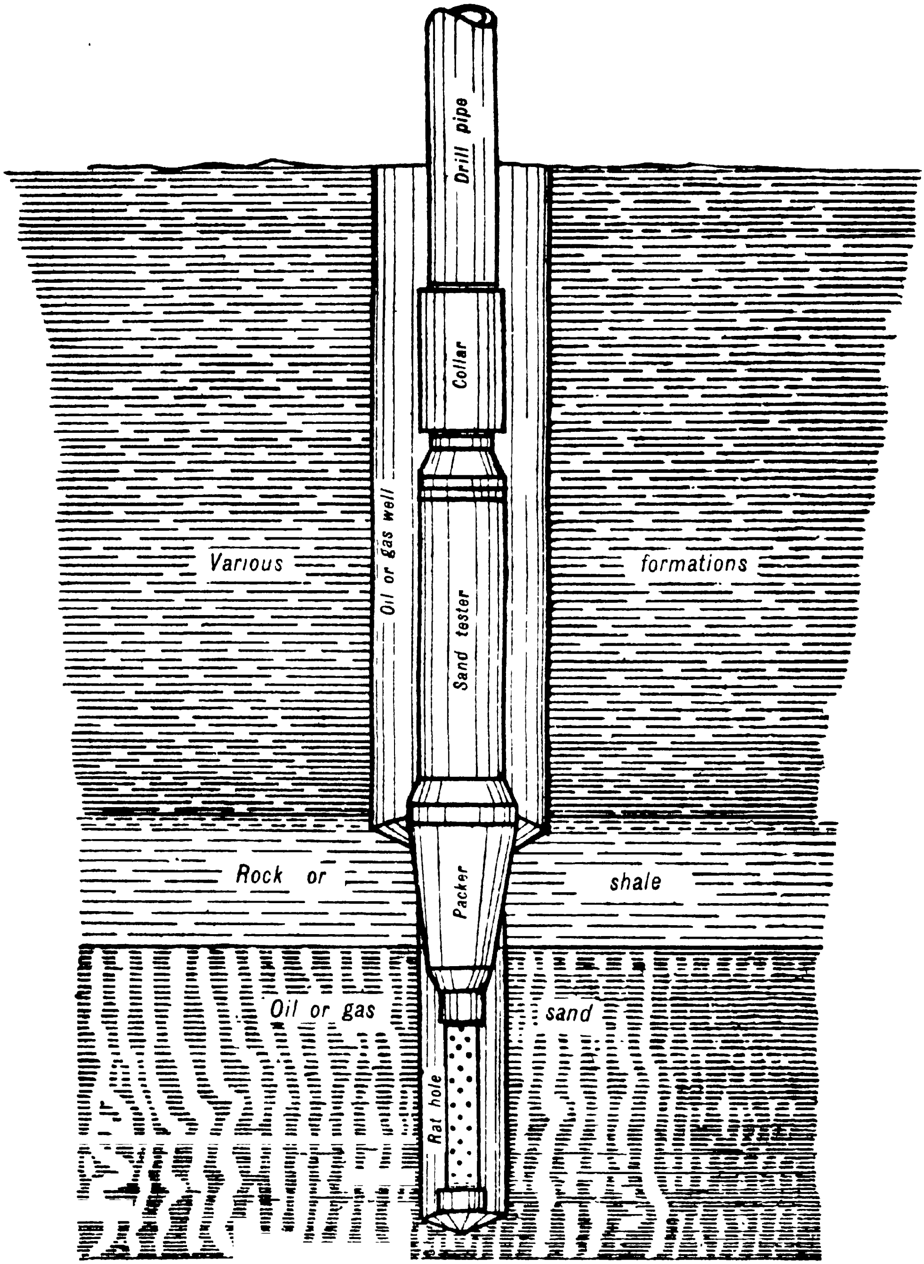
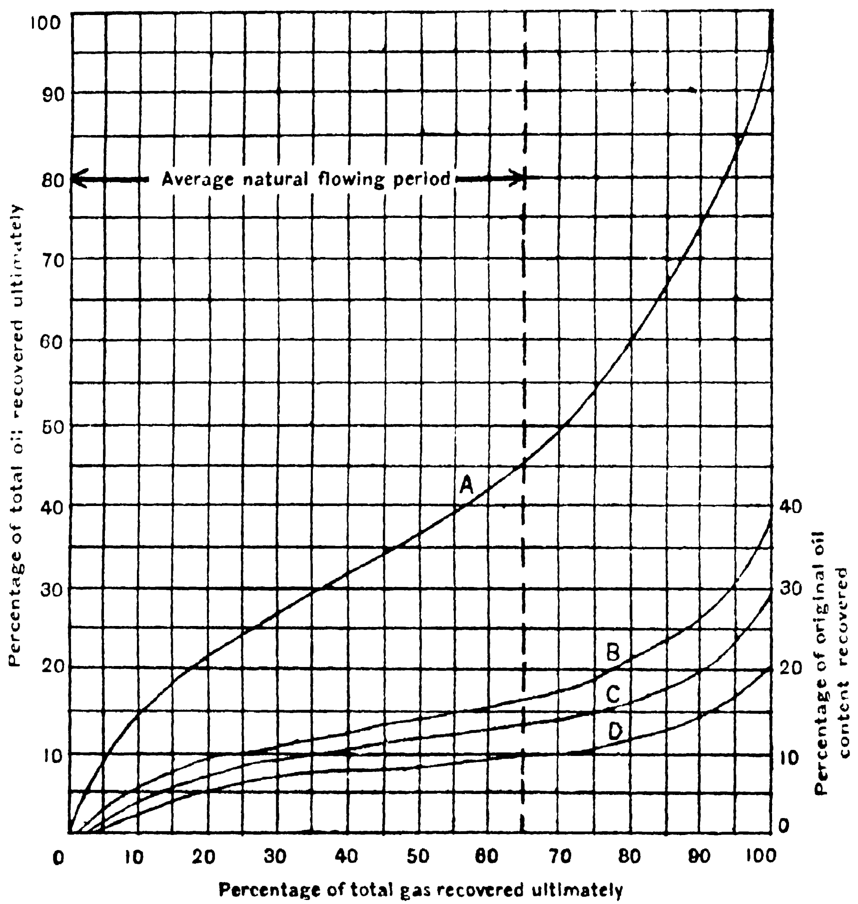


G. S. I. Calcutta.

THE FORMATION TESTER.



G. S. I. Calcutta

GRAPH SHOWING THE AVERAGE RELATION BETWEEN THE PERCENTAGE OF THE TOTAL OIL AND TOTAL GAS RECOVERED ULTIMATELY FROM 5 CALIFORNIA WELLS.

Curves B, C & D are based on the assumption that the percentage of oil recovered was 40, 30 and 20 per cent. respectively of the original oil contained in the reservoir sands.

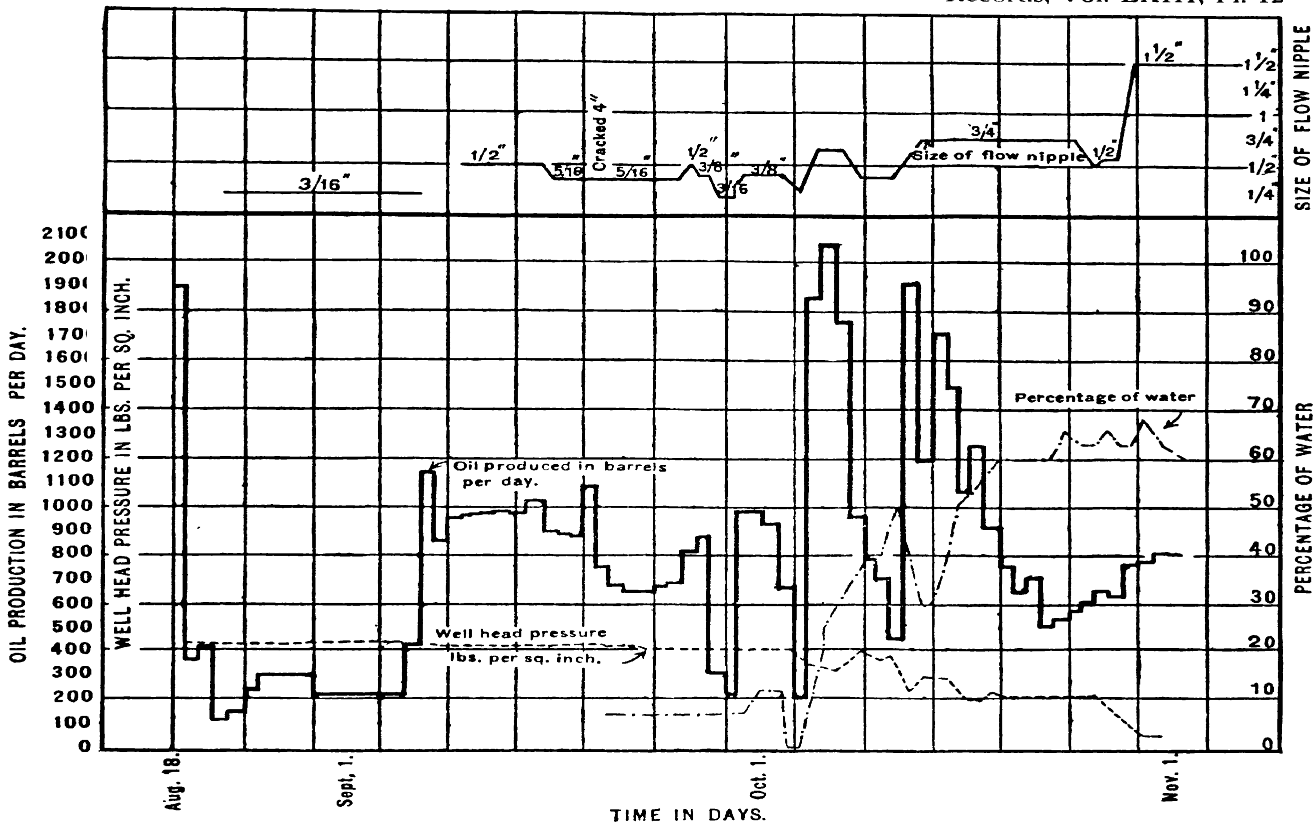


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CHART SHOWING RELATIONSHIP BETWEEN PRODUCTION, SIZE OF FLOW NIPPLE AND E NTAGE OF WATE

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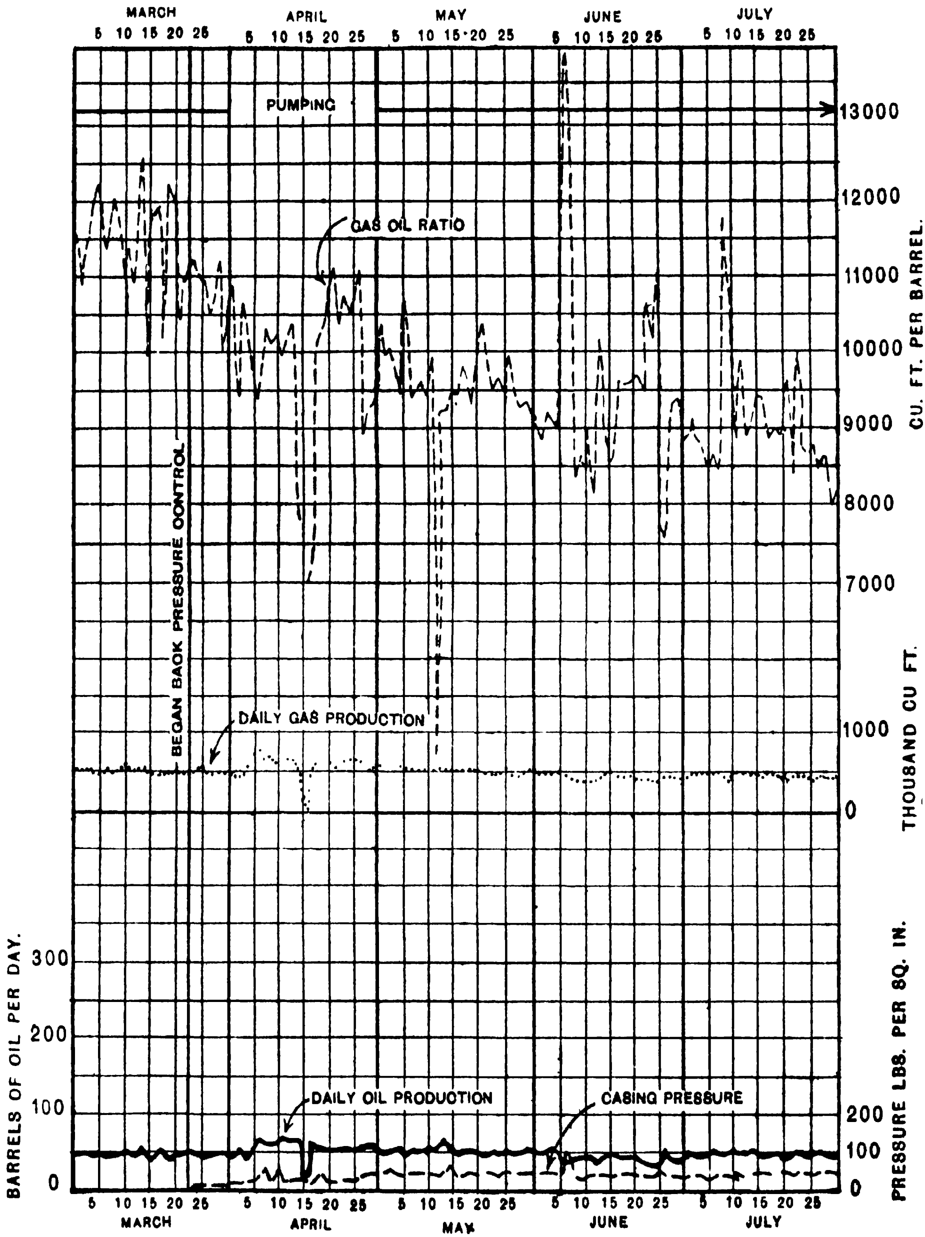
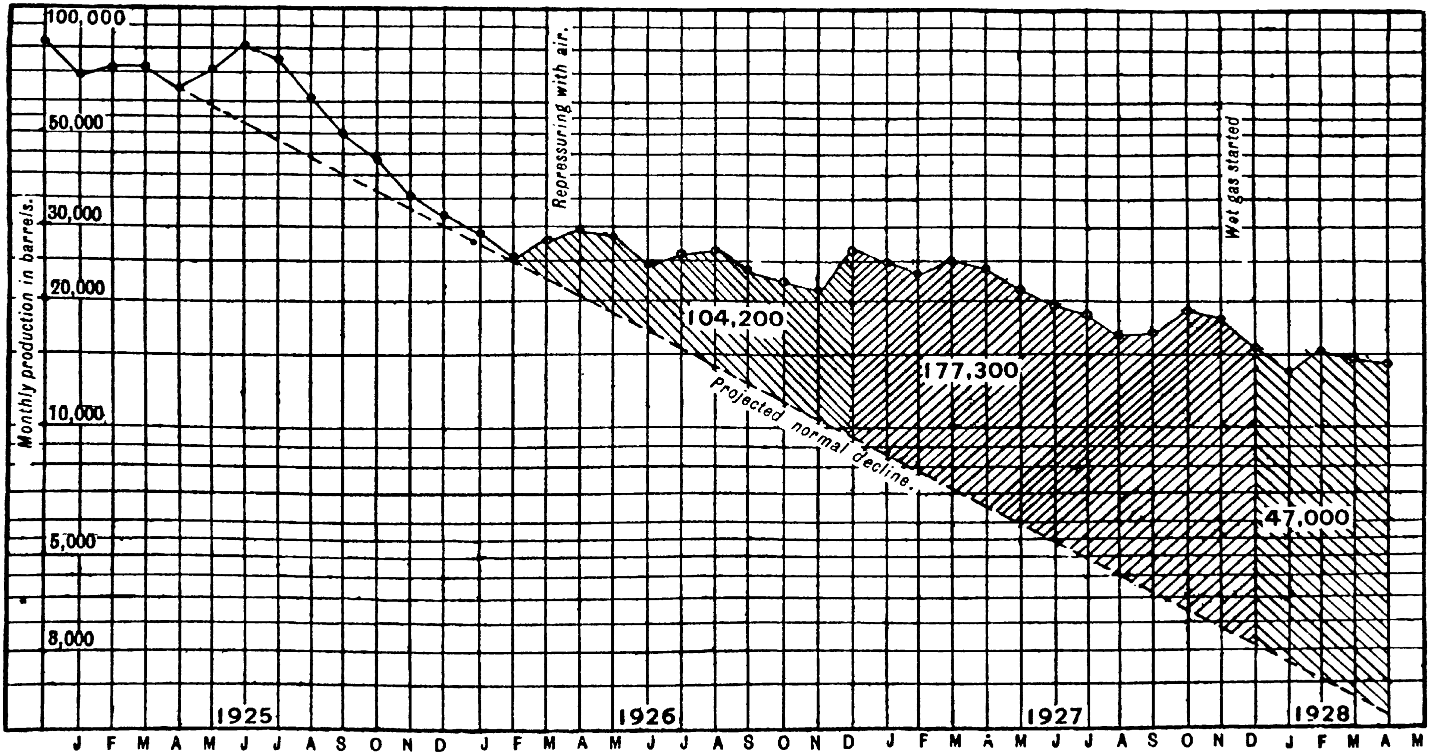


G. S. I. Calcutta

PRODUCTION GRAPH ILLUSTRATING GAS-OIL RATIO CONTROL BY MEANS OF CASING PRESSURE IN A PUMPING WELL IN DOMINGUEZ FIELD.



Litho. G. S. I. Calcutta.

GRAPH ILLUSTRATING RESULTS OF REPRESSURING WITH AIR.
Harmel Pool, Archer County, Texas.

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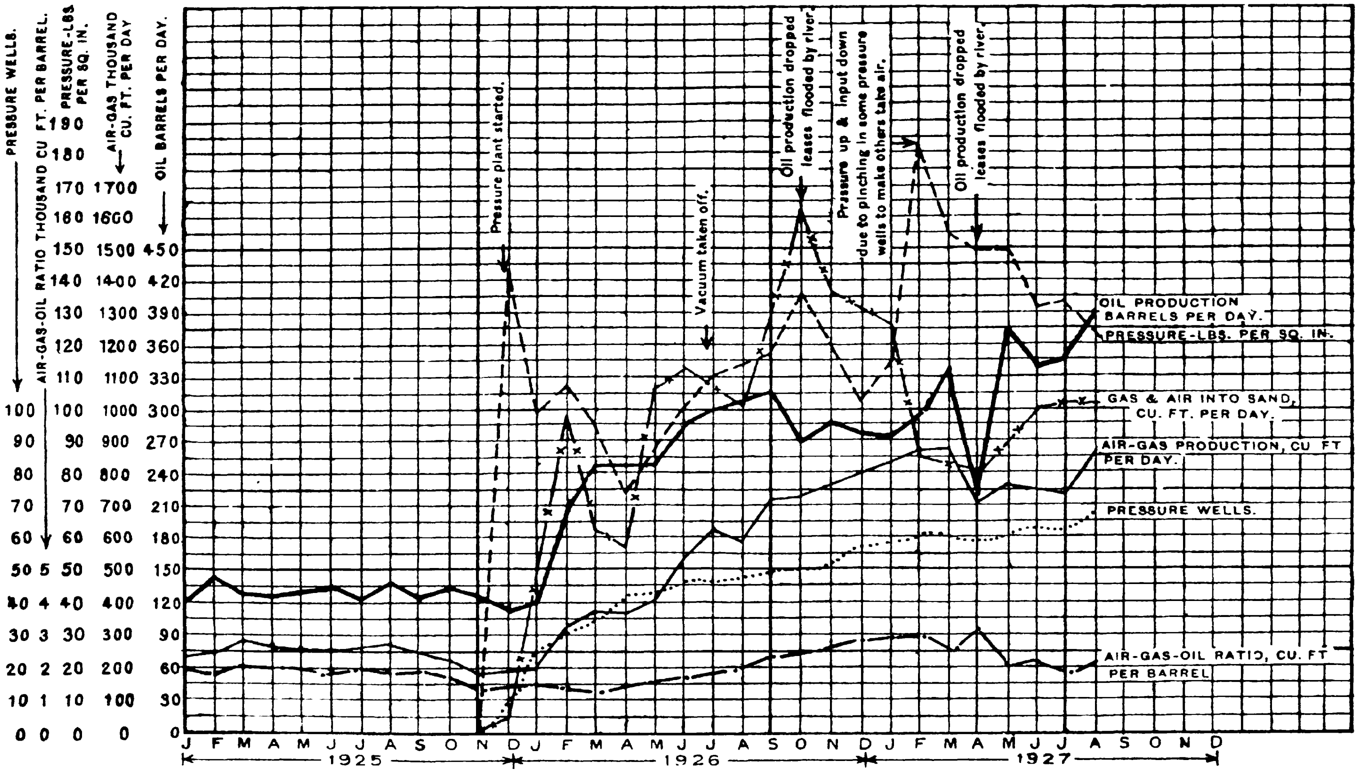
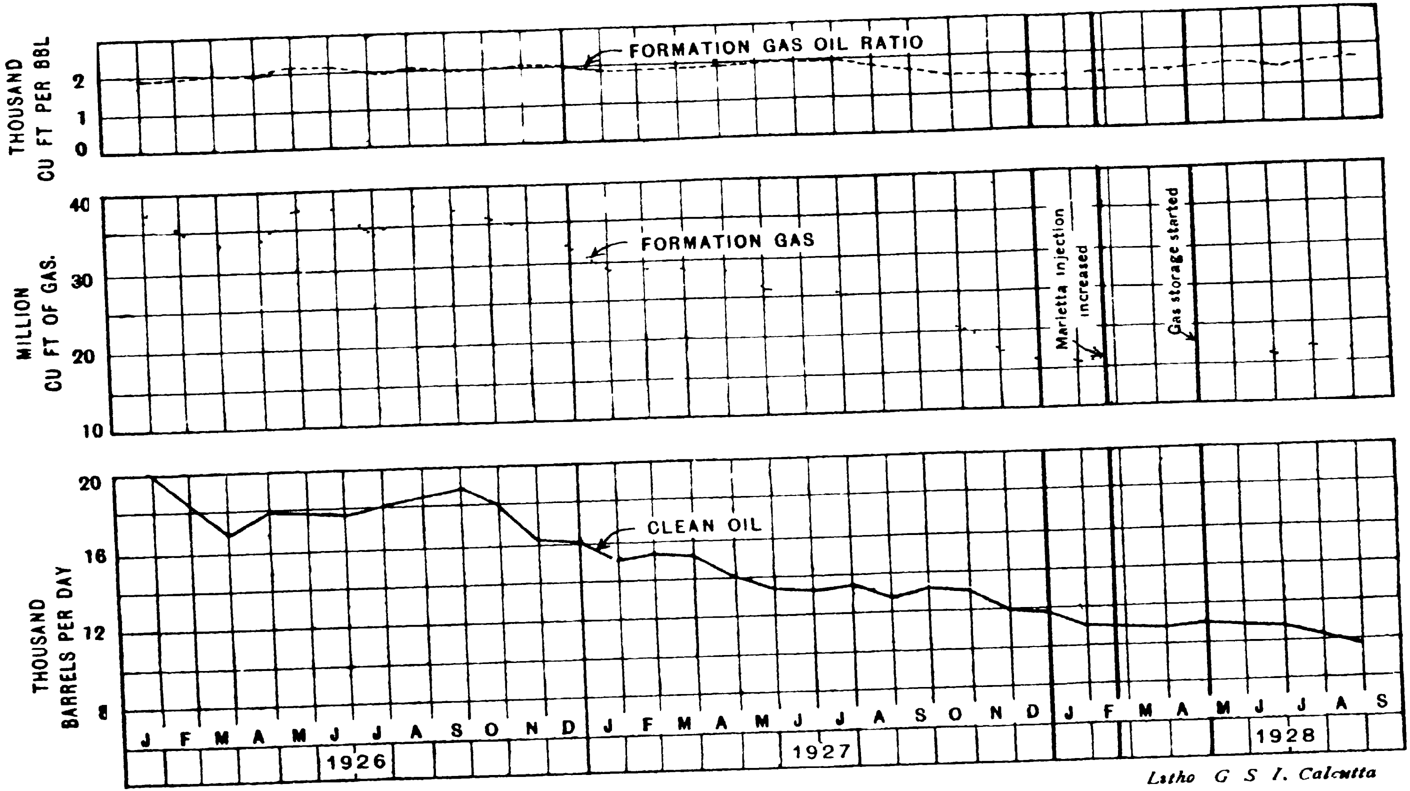


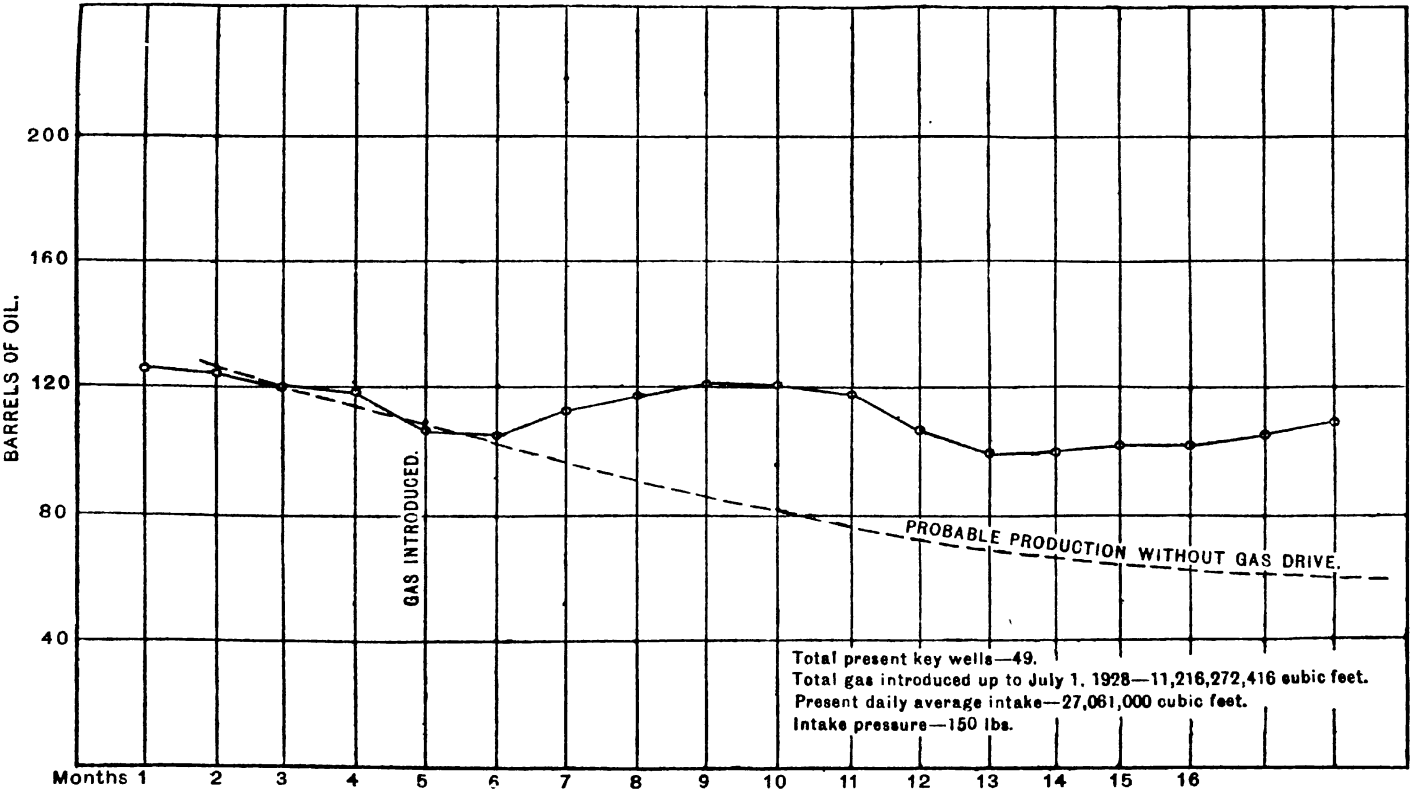
G. S. I. Calcutta

GRAPHS ILLUSTRATING THE RESULTS OF REPRESSURING. ALLUWE, OKLAHOMA, U. S. A.



Litho G S I. Calcutta

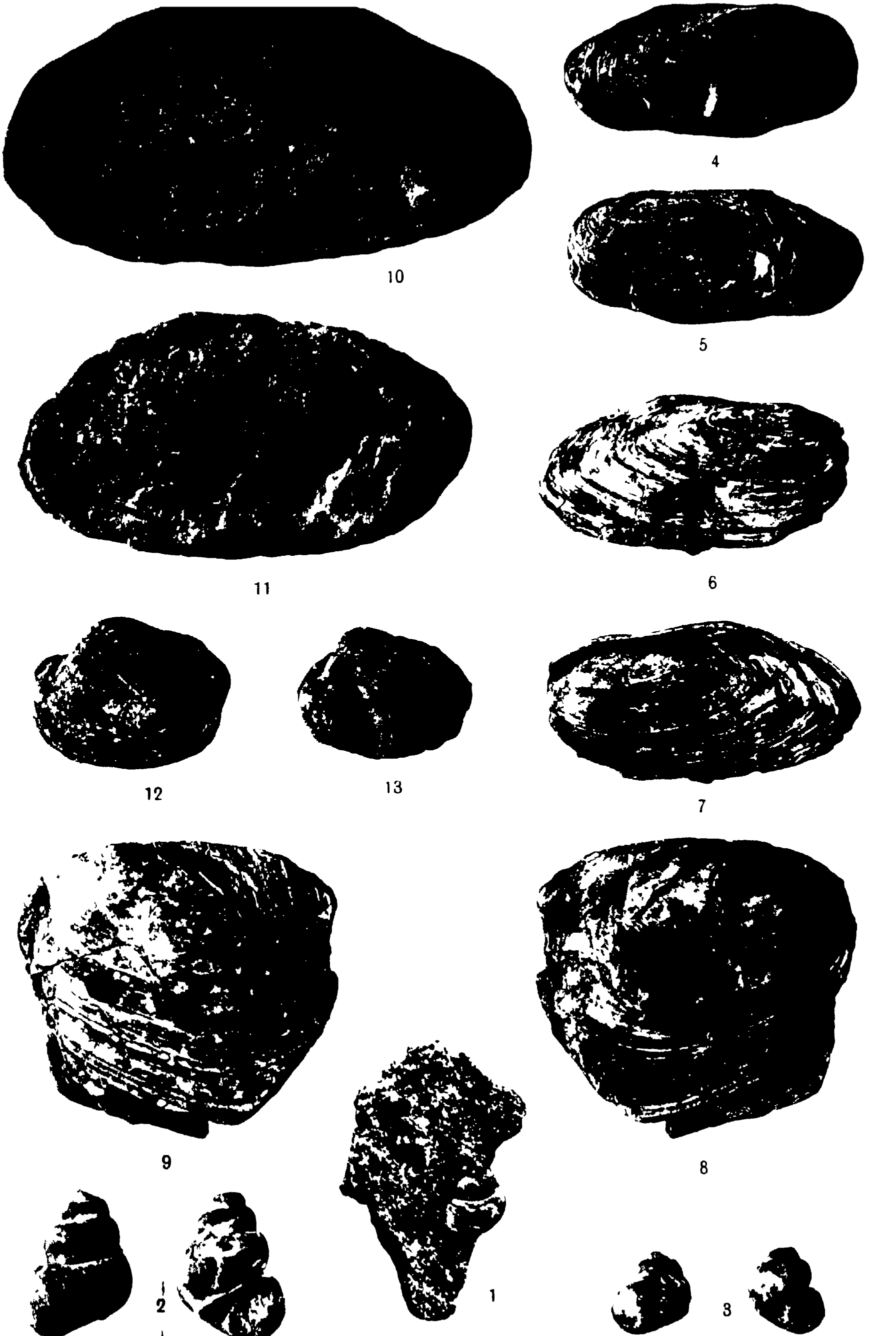
PRODUCTION GRAPH OF THE CALLENDAR, HELLMAN AND REYES LEASES, DOMINGUEZ HILL OILFIELD, CALIFORNIA.



Litho. G. S. I. Calcutta.

SALT CREEK GAS DRIVE.

Composite curve for 19 key wells showing daily average oil production for surrounding wells per key well.



S. C. Mondul, Photos. G S I Calcutta

FOSSIL UNIONIDÆ.